DESERTIFICATION: Monitoring and Control

Editor

A.K. TEWARI

DESERTIFICATION:
Monitoring and Control

Desertification is the process of environmental degradation arising from the fragility of dryland ecosystem. Under excessive human exploitation stability and resilience of desert environment are deeply damaged. It slackens and sometimes disrupts the natural process of recovery in major ecounits bringing it to the point of disaster. At this stage it becomes imperative to heal the ecological wounds of the susceptive region by identifying and eventually controling the factors responsible for such depletion. The present volume is an exploration into the universal problem of drylands. It synthesises the theoretical and regional frames of the question of desertification in the Indian drylands with indepth analysis of its monitoring, conservation and management. The authors are professionals in the field deeply involved in the fundamental and applied aspects of research n desert development. The target group of sers are the scientists, administrators and managers working in the field of geographical analysis, ecology, resource development, environmental policy, desert planning, and formulators of the comprehensive designs for national parks, protected areas and survival of species.

A. K. Tewari

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DESERTIFICATION
Monitoring and Control

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EDITORIAL

Interest on the problem of desertificatian has been viewed from different angles by scholars, politicians and policy makers yet the concern for their amelioration has always been the same. Three landmark events (UNESCO Conference, Paris, 1960, UNCON Conference, Nairobi, 1977 and IRDC Conferenee, Tucson, 1985) have deliberated the questions of environment and man in the desert and semidesert areas and renewed their concern on a single problem, how to control the contemporary eco-deteriorations made by man himself. The present volume is the updated version of the lectures, addresses and observations of the participants in a University Grant Commission's National Workshop held in the University of Jodhpur (India) during October, 24 thru November, 4, 1985 By virtue of its location in the margin of the *thar* desert, the University of Jodhpur took lead in designing most of its academic programmes, research directions and extension activities on regional problems of the Indian desert.

The workshop deliberations integrate the inter-disciplinary research advances in various departments of the Universities and research institutions in India. Major contribution came from the scientists of Central

Arid Zone Research Institute of India who are engaged in active research, development of new technology, field testing and application of laboratory findings in the arid and semiarid regions of India. The workshop drew 50 scientists from different parts of India out of which 15 presentations were actually received for inclusion in the present volume. Except for meeting the requirement of consistency and format no susbstantial changes have been undertaken in the original manuscripts. The copy right and the responsibility for the content of the presentations rest with the respective authors.

In the organisation and overseeing the academic deliberations, participants hospitality and field trips the assistance provided by the faculty and scholars of geography department, University of Jodhpur deserves special mention. The director/editor would put in record the role of Dr. Bhajan Lal, Dr. L. K. L. Saxena, Dr. S. C. Misra and Mr. Irfan Mehar who worked for the preparation and sciccessful completion of the 15 days workshop. Finally, the editor acknowledges with profound gratitude the valuable contribution of Professor Thomas F. Saarinen, Professor of Geography and Regional Development, University of Arizona, Tucson (USA) in writing a comprehensive introduction for the volume.

A.K. TEWARI

INTRODUCTION

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Our images and ideas of the earth and our relationships to it are evolving at a bewildering pace. When I entered graduate school in the early sixties there were no officially designated wilderness areas in the United States. There were no requirements to write environmental impact statements. *Silent Spring* of Rachal Carson, an often cited precursor of the American Environmental Movement of the 1960 s, had just appeared (Carson, 1962). In the ensuing decade the changing American environmental attitudes were reflected in a series of new laws culminating in the Natural Environmental Policy Act of 1969. The United Nations Conference on the Human Environment which took place in Stockholms in 1972 indicated that perspectives on the ecosystem were changing at the global level as well as in America. At that time the main impetus for action to protect the environment came from the rich affluent nations. They found that their environment priorities were not fully shared by many of the less privileged nations. This too has changed (Holdgate, 1982).

The term "spaceship earth" may be seen as a symbol of the rapid evolution of environmental ethics. Such a term was never used when I entered graduate school. When first coined it was regarded as a marvellous image to help people see the need to protect the earth's life-support systems and to get across the idea that we are all in the same boat, passengers hurtling together the rough space to we knew not where. Barbara Ward in *Spaceship Earth* used the image to express this sense of interdependence and community of human destiny; as well as the precursors of our total dependence on a "little envelop of soil and a rather larger envelop of atmosphere" both of which could be contaminated and destroyed (Ward, 1966).

Yet within a couple decades this exciting and useful concept has lost its lusture due to rapid advances in environmental ethics (Miller, 1988). Now the spaceship earth concept has been labelled "shallow ecology". What is now seen as necessary are sustainable earth ethics or deep ecology. Such ethics are based on the belief that humans are part of nature and that in satisfying our needs we should work with nature, that we should share the earth's finite resources with our fellow humans and all non-human species. Matter and energy are seen as finite and should not be wasted. "There is enough for everybody's need but not for anybody's greed" in the phrase of Mahatma Gandhi.

Deep ecology calls for us to distinguish between our wants and needs by harmonising life styles with natural cycles. In North America and other affluent areas on earth this would involve adapting a philosophy of voluntary simplicity based on doing more with less. More then are intellectual understandings of the general ways nature works is required. A direct emotional involvement with nature is necessary. This is accomplished by developing a sense of place, by finding a portion of the earth that we identify with. This can be in an urban, rural or suburban-area, or in a large or small geographical region. By identifying with the place we become sensitive to it, a part of it as it becomes a part of us. Thus we are driven to defend it against damage and to heal its ecological wounds.

We could regard the book *Desertification : Monitoring and Control* as the product of a group of Indian scientists who have selected as their place the arid zone of India. By carefully monitoring the human adjustments and maladjustments to this place they are sensitising each other to its essential qualities. In the long run this will enable other citizens of India and the rest of the world to better understand this portion of the earth. It could also instruct and encourage decision makers to make better adjustments to aridland ecosystems.

It is encouraging to see such dedicated efforts come to frutation. The Indian scientists, who have authored the chapters, show that interdependence and a sense of community among world scholars is becoming a reality, and that global environmental awareness is deepening, For they frequently refer to desertification studies elsewhere as they describe the unique features of their own arid areas. They have drawn upon information and gained inspiration from research in analogous areas in other parts of the world. Now this book will reciprocate as it provides aridland researches everywhere with a comprehensive view of desertification in the dry zone of India.

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RECENT ADVANCES IN MONITORING THE PROCESS OF DESERTIFICATION ECO-UNIT PLANNING

A.K. Tewari

I. INTRODUCTION

a. COMPLEX PROCESS: Desertification is a complex process of maladjustment between interacting forces of physiobiotic environment and their users. The natural deterioration of land resources (soil, vegetation and wildlife) may follow some long term physical changes like climate, altitude or changes in the overall behaviour of the earth system, but to a greater extent and within shorter periods such phenomena are triggered off by the users of land. Plants and animals use their habitats in interdepending feedbacks and interlocking chains known as ecosystems. But it is the man who has greater mobility and sustained energy to intervene the ecosystem in what so ever manner he considers profitable. For short range profitabilities man may even break the natural ecosystem adversely reducing the quality of environment. It may initiate desertification step by step - first in the form of decline in biological activity, gradually weakening the fragile balance of eco-units, and finally usurping the otherwise stable environment to desert like conditions. Literally deserts are areas uninhabited, desolate, barren, waterless, unattractive and uninteresting to man. The spontaineous chain reaction between organic (users) and inorganic (Land) elements to the loss of land quality is called desertification or desertization. Usually spatial limits of such areas are confind to the drylands of the world but it may sprawl to any marginal space. Due to low human intervension the core areas are mostly unaffected but the peripheral zones with high population density are prone to this hazard.

b. A CONCERN FOR MONITORING THIS PROCESS: More than one third of the total land area of the globe is prone to the hazard of desertification. Some of the early civilizations such as Indus valley, Mesopotamia, Nile and Persia succeeded in formulating human use centres at the desert margins. However, the modern màn has a limited success in establishing an economic foothold in such areas. It is partly due to disproportional growth of population in the semiarid lands and partly due to late commencement of desert development planning. Such areas have low degree of future return and higher susceptibility to drought and famine. From the risk zones we may conveniently drop several categories of dry zones such as cold polar, cold continental, cold uplands and tropical deserts of permanent nature, for, these are seldom used intensively. Then where we have to pinpoint our monitoring endeavours? These are the densely populated desert margins.

Although the ecorisk areas of the globe are distributed in almost all the latitudes, altitudes and in continental interiors or coastal zones, yet, they have a homogeniety in one character - the scarcity of water and a delicate balance of life forms at the threshhold of survival. Their ecological system is so finely tuned to the paucity of water that no biotic disturbance is permissible in a strict resource planning sense. In this context the present discussion concerns to project an eco-unit study in a desert region of India : the Desert National Park. Such areas are aimed to provide long range conservation of typical biospheric reserves to ensure self perpetuating growth of rare plants and animals.

Under the Man & Biosphere Programme (MAB) of UNESCO, the Advisory Board of the Indian National Committee in 1979 has identified 13 areas as environmental Centres/Biosphere Reserves in India such as Gulf of Manners (Tamil Nadu), Kanha (M.P), Kaziranga and Mannas (Assam), Namdapha (Arunachal Pradesh), Nilgiri (Karnataka and Kerala), Nanda Devi and Valley of Flowers (U.P.), North Islands of Andamans, Nokrek-Tura Range (Meghalaya), Sundarbans (Bengal), Runn of Kutch (Gujrat) and the Thar (Rajasthan). The planning of a desert National Park is just a beginning to this direction.

c. THE WORKSHOP OBJECTIVES : In the present workshop academicians from varied discipline have assembled for the first time to present their comprehensive technoscientific expertise in monitoring the process of ecodisasters. It focuses the present and future techniques of space watch system by remote sensing, computer aided techniques and conventional cartonumerical methods with a view to formulate an environmental ameliorational plans for hazardous areas. The participants and resource personnels have come from almost all the geographical areas of India - North east (Shillong, Imphal), Sutlej-Ganga plains (Kurukchhetra, Rohatak, Delhi, Aligarh, Lucknow and Gorakhpur), the Deccan plains and plateau (Hyderabad, Kolhapur), coastal plains (Madras, Waltair), Gujrat plain (Baroda) and the arid and semiarid plains of Rajasthan (Jodhpur, Jaipur, Bikaner, Ajmer, Beawar, Didwana, Bhilwara, Ganganagar, Chittorgarh). The objectives of the workshop are :

(i) To acquaint the teachers and scholars of Indian Universities/Colleges the present state-of the art in measuring the process of environmental deterioration;

(ii) to devise and apply field and laboratory methods for testing spatial and temporal dimensions of the natural hazard of desertification:

(iii) to perfect the technoscientific knowledge in assessing, monitoring, storing, presenting and sensing the overall aspects of ecodisaster and

(iv) to strengthen the national and regional consciousness for ameliorating the supply of natural flow resources in fragile ecounits and to spread the application of new tools and teaching materials for an interdisciplinary research.

WORKSHOP DESIGN

The workshop addressed the following themes:

- Conceptual frame
- Field survey methods
- Cartographic tools
- Quantitative monitoring
- Remote sensing techniques
- Recent advances in environmental studies
- Specific field study in areas of ecocrisis
- Monitoring physical processes
- Monitoring human processes
- Deforestation and desertification
- Ecological imbalances in food systems
- Issues in environmental planning and oasisification

II THE SPATIAL ATTRIBUTES OF THE DESERT NATIONAL PARK

a. THE REGION: The spatial system in a desert region impresses upon the life forms in two contrating ways : the abundance of warmth, light and wind with an extreme scarcity of water. As a sequence to these unfavourable condition, the landscape appears desolate, wild and devoid of any natural cover of vegetation. In a sense its unattractiveness to human occupancy is a boon for desert wildlife which remains unharmed and truly virgin by nonintervention of human species. The discussion deals how a specific habitat planning of desert ecosystem can be organised into an organic complex wherein each independent unit sustains one another by interacting feedbacks. It examines the aspects of ecological energy requirement, entrophy levels, biological adaptibility and preservation of a recreational space for human use in a proposed national park located deep in the *thar* desert. The richness of the natural ecobeauty of Indian desert is to be preserved in this national park.

The Indian Desert National Park is being developed in an area of 3,161 sq. km. in the districts of Jaisalmer and Barmer (Lat. 26°27'N, Long 70°30'-71°10'E). Following the recommendation of National Commission on Agriculture and Indian National Committee of MAB, the Rajasthan wild life Department has taken the work of this park under the Desert Development Programme (DDP). Compared to other national parks of the world, such as Canadian National Park (80,000 sq.km.) Tsava National Park, Kenya (8,000 sq. km.) and Serenghati National Park, East Africa (5000 sq. Km.), the proposed eco-unit is quite small, yet it will be the largest National Park for a desert region. Its major objectives are to understand the life cycle of desert flora and fauna and to preserve their biological processes in a natural habitat. The Union Ministry of Rural Reconstruction (MRC) has allocated Rs. 25 million for this project apart from what is being done by the state of Rajasthan.

The Great Indian Desert has some of the most spectacular wild life preserved in Jaisalmer-Barmer region. It includes the most elusive and secretive bird like the Great Indian Bustard. The bustard family was once widespread in the entire arid and semiarid parts of India, Pakistan, Middle east and Central Asia. But due to serious persecution by the rich Arabs its number has gone down. The species of Houbara Bustard has suffered most. It has become extinct. These birds migrated from the semiarid areas of Aral-Caspian region (U.S.S.R) during winter and laid eggs in the deserts of Arabia, Pakistan and India. Their young ones were fed on the ample locusts swarms frequently visiting these regions. But due to some traditional liking of Houbara bird meat for sex stimulent, the birds were brutally hunted. However, in the Indian counter part of the desert they were preserved by the native folk.

b. DESERT ECOSYSTEM : The ecosystem consist of interacting natural processes within the confines of a particular space. It also includes a sequent occupance system of man himself comprising his cultivated plants, domesticated animals, his consequential interplays, attitudes, objectives, technical skills and cultural menifestations. In the proposed national park the critical desert ecosystem of endangered species will be preserved for recreation and research. In the favourable environment the natural vegetation will regenerate food for the primary comsumers. The wild animals of *thar* thrive on tender shoots of crops, berries, grasses, herbs and shrubs.

The desert plants are specially adapted to arid conditions. The major forms of adaptation are water conservation, thermal protection, structural adjustments, behavioural and synoecological modifications. By virtue of their computer tailored combinations of physiology, morphology and anatomy these life forms can withstand long spells of drought. The annuals evade dry spells by rapidly completing their life cycle during the period of monsoon and passing the remaing part of the year lying dorment. Their scattered spacing and root development help in this process. The desert fauna also follows a diapose state during dry season and increased activity at the time of inflorescence. The floral activity is further energised by temporal brilliancy in colours and penetrating odours during a limited period which attracts pollen carriers. The succulents have an extraordinary capacity to store moisture inside their roots and stems and protection from all possible attacks of evaporation or animals. Their ecological armanents are thick and spiny bark, hairy and waxy leaves and thorns. The ephemerals are not truly xerophytes for their activity fluctuates with the season of rains. Their physical adaption is mesophytic

Following the advent of man, the natural position of desert ecosystem transformed. First he become a potential destroyer and later a planned creator and conserver of the productivity and hospitability of desert environment. In the beginning his intervension was quite benevolent with marginal impact on animal and vegetation groups but with increasing technologies and higher needs he was able to exploit the entire biological reserves. Unplanned grazing conventional agriculture, war exercises and liberal hunting are the greatest enemies of desert. A slight loss of biomass will cut off the life stream of the animals, deprive them of their foods and shelter. As a creator, he has reorganized the desert space-brought new sources of water, planted more trees and preserved the species of animals. This is what we call is planning of ecounit.

c. A HUNTING FREE ZONE : In the proposed national park there will be no sanctions for animal hunting. All the natural pools and *thals* in between sand hills (dhrians) will be developed into winter homes of the visiting species of birds in the Indian desert. The main winter visitors are lesser bustard, Imperial sandgrouse *(Petrocles exustus)*. Kashmir raller *(Coracias garrul)* etc. These birds land in this region in flocks of millions during November and December. On the shores of interdunal basins colourful flowers of Kair *(Capparis decidua)* and Rohira *(Tecomella undulata)* blooms. The landing of these migratory birds is a phenomena unparelleled in beauty. The scheme has three stage operational programme involving a total expenditure of Rs. 60 million over a period of five years. In the first stage the entire bio-reserve will be classified into a core zone free from any human intervention. It will be surrounded by a girdle belt of controlled grazing and restricted farming. It will help the desert bushes and supporting flora to grow wild and provide a camouflaging space for the threatened species. The park has more than 60 bustards, hundreds of chinkaras *(gazella pallas)*, common bustard *(Chlamydotis undulata)*, Great Indian Bustard *(Choriotis nigriceps)*, Indian courser *(cursorius coromandelicus)*, grey patridge *(Frencalinus pondi cerianus)*, rosy pastor *(Pastor roseus)*, starlings *(sturnus vulgaris)*, mynah *(Acridotheres tristis)* and innumerable tilors, wild cats, desert fox *(Vulpis pusilla)*, palm squirrels *(Funambulus pennanti)*, falcons and game birds.

To achieve this end several grass and bush pastures (phog), several water reserviors and thousands of trees (Khejari, kair, babul and ber) have been artificially planted and maintained. The water of Indira Gandhi Canal is also diverted to keep the subsoil moist.

Secondly, a research centre will be established to conduct special studies of rare species. It will be coupled with a chain of honey producing centres where bee keeping will be monitored after introducing more exhotic species. It will increase the natural process of honey storage and will help in the cross pollination of desert vegetation. Honey and wax marketing will be developed on modern lines.

Finally, an intricate network of tourist observational posts, camps, *machans* and tracks will be developed. It will boost the regional economy of Jaisalmer desert.

d. FOSSIL WOOD PARK : Under the National Desert Park Scheme (NDPS) the state tourist department has added a new dimension. At Akol some 17 km. from Jaisalmer, a fossil wood park has been planned. In this area fossil wood logs are found in great number. The first fossil wood area measuring 7 meters in length and 1.5 metres in breadth was discovered by the Geological Survey of India as early as 1900. Later more than 60 twisted and brittle pieces of log fossils have been found, the biggest being 7.5 metres long. It is assumed that these fossils have been deposited in this area by the wild rivers millions of years ago from the dense lower Jurassic forests that once stood in and around Jaisalmer. The trees must have been nontropical in nature such as pine. The Pleistocene desertic conditions and recent ground water circulation in this fossil rich area have manifested an architectural design to the buried woods resembling the superb carvings of Jaisalmer city.

MONITORING OF DESERTIFICATION A CONCEPTUAL FRAME

K.A. Shankarnarayan

I DESERTIFICATION-AN OVERVIEW :

Desertification to an ecologist is a systematic phenomenon involving climate, soils, flora, fauna and man. It may be regarded as a form of deterioration of the ecosystem due to change in human adaptation. Desertification arises from the fragility of the dryland ecosystems which under excessive pressure of humen use lose productivity and ability to recover. Stability and resilience are major factors in the viability of all the system-social and cultural as well as physical and biological.

Desertification, therefore, can be defined as a package of processes which brings about certain basic changes in a particular ecosystem and converts it from a relatively nondesertic to a desertic terrain. This involves an interplay of climatic, edaphic and biotic factors which may (a) work through time starting with a climatic accident and ultimately resulting in the formation of a desert, or (b) to accentuation of the arid conditions within an already desertic terrain, or (c) cause a creep of the desertic conditions within a desertic tract towards its adjoining areas (Mann 1977).

Although desertification can develop from natural cause alone and in any climatic zone, the U.N. conference at Nairobi in 1977 mainly focussed attention with desertification that derives from interaction of human use system with natural ecosystem in the arid, semi-arid, sub-humid and humid zones. For these reasons desertification must be diagnosed and monitored through the whole range of physical, biological and social processes relevant to ecosystem and human adaptation of drylands. When the balance of an ecosystem breaks down due to desertification it may be difficult to constitute a viable human use system as to restore primary productivity. As a result the land may be totally lost to human community. Hence if people are mainly responsible for desertification, it is equally most efficiently combated by diagnosing and arresting the social and economic processes that lead to it. (ESCAP 1983).

Thus desertification is mainly a man made problem which leads to the environmental degradation of fertile lands. The basic cause of desertification is the interrelationships between the physico-environmental system and the various human adaptation. This is because the environment (when defined as the sum total of the conditions that control human activities) are under stress of human needs or adaptation (when adaptation is defined as the various means the human being adapt to survive themseleves). Thus it is the human activities that primarily initiate desertification processes. With this, the quality of resource management should be added or considered. The skill is also important. Over exploitation of resources cannot be ignored. The two combine to add to the intensity of environmental degradation or desertification hazards. Some of the main human and biotic interactions that are causing desertification hazards are:

i) Uneconomic land-use-cultivation on the sand dunes, marginal lands affecting adjacent fertile lands are a menace to soil erosion.

ii) The intensive and uneconomic or over exploitation of water resources leading to rise water table, seepage problems and problems of increased salinity.

iii) Uncontrolled grazing and indiscriminate cutting of trees or over exploitation of grazing lands and forest resources leading to drought, soil erosion, deterioration of soil fertility and stunted growth of trees.

These activities cannot be totally suspended but definitely subject to control by proper management. Accordingly desertification exists in all the areas and will continue to be a problem. (Shankarnarayan & Sen, 1985).

II MAJOR PROBLEMS OF DESERTIFICATION INDIAN SUB-CONTINENT

According to UNEP's estimate (1977) a **total** area of 4,361,000 sq. km. in Asia and the Pacific has been involved by desertification. This has affected a total population of 28,482,000 of which the urban based, cropping based and animal based are 27%, 54%, and 19% respectively. This paper is designed to provide a brief overview of the problems of desertifications in India, Bangladesh, Nepal and Sri Lanka.

(a) India:

In India arid zone covers about 12 per cent of the country's geographical area (320,000 sq.km.) covering parts of Rajasthan (62 per cent), Gujarat (19 per cent), Punjab and Haryana (9 per cent) and Andhra Pradesh and Karnataka (10 per cent). In addition to this, an area of about 70,300 sq.km. of cold desert exists in Ladakh in Jummu and Kashmir. The three-fifths of Rajasthan lying west of the Aravallis constitute the bulk of the arid zone of the country. Considering the resources available, the density of population of about 64 persons per sq. km. is quite high. Inspite of low productivity the Indian desert sustains a fairly high population of livestock. The high pressure of livestok on grazing lands, specially in view of its low carrying capacity, results in the over use of these lands and in depletion of natural vegetation often necessitating migration of man and his livestock in search of new pastures.

The foregoing and other biotic and socio-economic factors reveal that the region suffers from a number of problems. The man/land ratio is fast declining. As a consequence more and more marginal land is being brought under the plough resulting into a substantial increase in sown area at the expanse of grazing lands. But at the same time the livestock population has increased leading to an overexploitation of the shrinking grazing lands. Cultivation on sand dunes and marginal lands is not only improper but is also a menace to soil erosion. Similarly, the increased population has led to the increasing demand of wood for fuel and has led to an overexploitation of vegetation resources.

Increased desertification problems are also evident in the form of increase of salinity hazard, seepage and water logging problems, rise of watertable, shifting of dune and aeolian sands in the irrigated areas of Indira Gandhi canal command areas due to overuse of canal waters and overexploitation of water resources. Due to intensive use of canal irrigation, water table has reached only within a limit of 30 to 60 cm in Borpal area near Suratgarh causing a number of waterlogged areas. The rise of water table and seepage problems have threatened the existence of the sites of pre-historic excavations of Kalibanga and Rangmahal in Ganganagar district.

II. AN ASSEMENT OF ENVIRONMENTAL DEGRADATION IN THE ARID ZONE OF RAJASTHAN:

The inherent vulnerability of the land and intense biotic pressure have combined to set in a process of deterioration within the arid zone. Different manifestations of this process were quantified in respect of a 2000 km² area in Luni basin as a case study for presentation at the U.N. Conference on desertification in 1977. The results of such studies carried out for Rajasthan desert as a whole are presented in Table 1.

(b) Bangladesh:

It has been reported by Bangladesh (ESCAP 1981/83) that process of desertification has been evident in the following regions:

i) Southwestern region (all of the lands south and west of the Ganges-Padma-Lower Meghana river) plus adjacent area north of the Ganges in Rajshahi and Pabna districts. Geographically this land comprises the Bagri region and S.W. lower Ganges plain (Chatterjee 1940) or Moribund delta of west and the tidal saline flood plain of the mature delta and immature delta (south-Sunderban) (Bagchi 1944; Rashid 1977). This comprises a total area of about 53,760 sq. km. It is conjectured that the low water flow of the Ganges in dry season have caused a chain of adverse effects specially on the agricultural sector. The salinity from the Bay of Bengal intruded into the river and the land masses in the south western region of the country affecting the prevalent system of agriculture. Salinity showed marked increase from a normal average of 500 to 1000 micromhos per centmetre to 13,600 micromhos per centimetre in April, 1976. Salinity penetrated about 132 km. further inland from the normal incursion limit of about 13 km. upstream of Khulna town. General observation; however, is that the increased salinity in extreme S.W. part is due to the saline inundation from the sea. The increased urbanisation and industrialisation in Khulha area has also led to the over-exploitation of water leading to the increase of salinity hazards like that of adjacent Calcutta area of west Bengal. Besides the Bagri region or the Moribund delta including mature delta (saline flood plain area only) has been known for its salinity and low water supply since long. The Moribund part of delta is characterised by rivers choked with sand and unable to carry much water except when the Ganges is in high flood. The associated slightly higher land to the south has been explained by Strickland (1946) as the rise of the tide which has led to rapid deposition of the silt carried by the once active rivers. The findings indicate a tectonic origin. It is evident that the main distributaries of the Ganges never flowed through this region and the small ones that did lasted a few centuries at most (Rashid, 1977). Actually drought condition is not so acute and virtually does not prevail here except to a very small extent in the Kushtia area which has a very hot summer and relative low rainfall like that of adjacent Murshidabad and Nadia area of West Bengal.

ii) Barind tract, Rajshahi district 1267 sq.km. to a very low extent due to uneconomic utilisation of lands, and

iii) Madhupur tract Myemensingh 12,505 sq.km. probably due to over exploitation of vegetative resources and overgrazing.

In a deltaic and high rainfall area like Bangladesh, desertification problem should not exist unless the resources are uneconomically exploited by the inhabitants. The problems so far posed are i) Salinity due to total inundation and over exploitation of water resources due to increased urbanism and industrialisation. ii) Increased pressure of population on land and iii) Over grazing and deforestation in Myemensingh area praticularly in Garo hills adjacent to Meghalaya plateau of India.

It is also possible that the shifting cultivation *(Jhum)*, rapid deforestation and industralisation may lead to desertification in the Karnafuli basin, hilly and ridge and valley terrains in Chittagong hill tracts. These require investigations.

(c) Nepal

In Nepal, the regions indicating the symptoms of various desertification processes and their effects may be found in (a) Trans-Himalayan region, which is heavily overgrazed, (b) parts of the humid mountains and hilly region where as a result of population pressure on land, accelerated soil erosion and frequent landslides are symptoms of unprecedented degradations of land with a consequent declining trend of productivity and lastly, (c) the Terai plain which is exposed to severe floods in each monsoon with increasing trend of bed load deposition in rivers and possibly some wind erosion during dry season. This is an area of discontinuous strip-about 16 to 32 km. broad with large areas of *Savannah* and *sal* forest.

The problems of desertification have arisen mainly from the following human interferences:

i) Widespread deforestation to meet the increased demand of fuel for ever increasing population.

ii) Overgrazing-particularly the semiarid tract opening to the Tibetan plateau where forced grazing over limited pasture land has led to desertification. An equally desperate situation is occurring in hilly areas.

iii) Cultivation on the rainfed steeply sloping lands and other erosion prone areas which is a menace to soil erosion.

iv) Clearance of forests in Terai area for resettlement and cultivation inducing water erosion.

Decline of entire forest in Nepal from 6.4 million ha to 4.8 million ha from 1964 to 1974 and to 4 million ha during 1980-81 indicates that the forests in Nepal are really in a critical state. The deforested and overgrazed areas and shifting cultivation present a gloomy picture.

(d) Sri Lanka

Drought conditions prevail in the north and eastern part of Sri Lanka where most of the rainfall comes in the N.E. monsoon months (60% of annual total) and the intermonsoon months (Sept. to Nov.).

A secondary maximum, due to the effect of "little monsoon" and its convectional and cyclonic rains occurs in the north central or Anuradhapur areas in April and May. The rainfall here is subjected to considerable variability and frequent droughts. Process of desertifications are evident in Sri Lanka in the following areas:

i) The low land dry zone: a) the W.coast, b) The Jaffna peninsula and island; c) The E. coast lowlands; d) The sea coast, low lands and e) Bintenne

ii) The Central Massif or the highland of the east; a) the E. Kandy region and b) the Uva basin. Thus about 70% of the island is subjected to desertification hazards.

The problems of desertification in Sri Lanka have arisen mainly from the following factors;

i) The movement of the sand from the eastern and southeastern coastal regions towards the Jaffna peninsula or northern centre or Anuradhapur area due to increased cultivation practices on these dunes for coconut and paddy (like Batticaloa region) in the marginal lands.

ii) Overgrazing and deforestation in the Central Massif particularly in Kandy plateau and also in northern centre of dry zone in Anuradhapur area.

iii) Increased cultivation practices in the Jaffna area to meet the demand of the increased population leading to shrinkage of pasture lands and overgrazing.

iv) The restoration of old irrigation works of the dry zone like the vicinity of Trincomalce, Anuradhapura has led to over exploitation of water table leading to the rise of water table and salinity problems.

v) Increased salinity in the coastal areas and tidal invasion through the consequent radial streams.

vi) Expansion of Chena cultivation system, the oldest form of rural cultivation in Sri Lanka is alarming as it has already induced desertification problems in dry zone This is done by construction

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or restoration of tank by clearing the forests below which highland rice is cultivated. The system has influenced on deforestation, over-exploitation of water, shrinkage of pasture land, loss of water by siltation, expansion of cultivation on marginal lands.

III. SPREAD OF DESERTIFICATION IN INDIA

The arid zone in India constitutes a significant portion (12%) of the geographical area of the country. It extends over a wide latitude covering both penninsular and extra-penninsular region. The northern portion of the arid zone is the continuation of the major Afro-Asian hot desertic region. Biogeographically, the biota of this tract holds 'western' affinities to a great extent. The cold arid tracts of Ladakh located in the Himalayan zone, depict entirely different biogeographical attributes.

Taking into account the manifestation of aridity in the natural setting and ecological features, the 'Core region' of the arid tracts of this country, including a small 'extremely arid' area, are broadly restricted to Rajasthan and its neiglbouring states of Gujarat, Punjab and Haryana. The focal centres for manifestation of desertification are also most pronounced in the Rajasthan region, especially in view of the intrinsically 'desertic' naure of this zone. As such, the bulk of investigational and implementational activities of various agencies have been to an extent, restricted to this tract. Much of the statements of this report, consequently, pertain to the Rajasthan State and its proximal areas.

The causative natural factors of aridity and desertification, are the inherent climatic conditions. the geological and geomorphological setting. The rocks are submitted to extreme temperature variations, with resultant fragmentation and accumulation of detrital sand which are easily transported by raging winds. High evaporation and low precipitation combine to create conditions which facilitates salinization of the entire tract and accumlation of minerals in the ground water and surface water. Soil development is relatively poor due to the low organic detritus obtainable in the tract, as the shortage of water sustains meagre vegetation, with fast removal of cover by winds. (DST CAZRI 1981/83)

(a) Rainfall trends

Analysis of precipitation records for more than seventy years reveals that the occurrences of large deficit years are more frequent in the drier parts of the arid zone, with values exceeding 220%. Five-Year moving averages for the period 1891-1975 shows that the large deficit rainfall spell during 1962-71 (commencing in fact from 1956) is only comparable with conditions during 1895-1905. The 1901-60 period recorded only 3-4 spells of below normal rainfall conditions of small magnitude.

Incidence of drought years has a multiplier effect on desertification. The conditions during the 1962-71 drought phase may have signiificantly contributed to the deterioration of the arid zone in India.

(b) Dust Storms

The frequency of dust storms rises with reduced precipitation in the preceding year. This is very significant in aggravating erosion and desertification by the ultimate removal of soil cover by winds. Measurements of dust during 1973-75, from the surface and 3 meters above, recorded 0.50 to 4.20 quintals per hectare on a dust storm at a Jodhpur, and 5.11 quintals at Jaisalmer. The removal of grass cover from 2007 sq.km. caused the depletion of 1065 cubic metre of soil in three years-a loss of 0.53 metres of soil depth.

Observations indicate that the size fractions of the dust samples include fine sand (55-75%), clay (6-15%), silt (14-39%) under various land use conditions, and at various heights from land surface to 3 metres above. The significant portion of silt

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in these samples indicates movement of fertile eroded soil over large distances. In fact, dust rises to more then 5000 metres over the Indo-Pakistan arid zone - the cause for the midtropospheric divergence that reduces rainfall in the area, despite the presence of moisture.

(c) Shift of aridity

The variation of the aridity index line of 80 computed by Penman's method studied for the 1901-70 period reveals an eastward shift during the first two decades of the twentieth century. Thereafter, there were minor to an fro oscillations, becoming more marked in Churu in the north and Jalor in the south, indicating maximum aridity eastward from 1951-60 in Churu and 1961-70 in Jalor. These studies imply a possible spread of arid conditions in the southeast.

(d) Geology and Geomorphology

The following basic geological hydrological and geomorphological conditions have contributed to the aridity and desertification in this tract.

1. Recurrent aridity in the geological history of the tract, with a particularly significant phase of wider extent in the early quaternary, accompanied by disorganization of drainage, in the Luni and Ghaggar basins and other northeastern zones (Kantli Mendha etc.), creation of inland basins with ephemeral, centripetal drainage, salt lakes and basins and a desert landscape of dunes, bornhardts and other associated features. As a result considerable tracts outside the present limits of the arid zone, in eastern Rajasthan are stabilished dune fields, with some pedogenesis. These zones are sensitive to irrational land use practices, being well within the semi arid belt.

2. Even after an interlude of ameliorating humid climate from 3000 to 1000 B.C. during which

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the Rangmahal culture thrived in the Ghaggar, a second arid phase set in, which is still continuing. Thus, the terrain did not have time enough to recover from the effects of the earlier phase of extensive aridity. This second phase of aridity once again led so further disorganization of drainage, creation of an inland drainage tract in the northeast Rajasthan area, dune fields and sand sheets and susceptibility of rocks to erosion producing features like tafonis, bornhardts, rock pediments, etc.

3. The present configuration of the Aravalli ranges effectively precludes the beneficial influence of the monsoons to a notable extent, in the arid tract to its west and provides the eastern climatic barrier of the zone.

4. The geomorphic setting of the Aravalli ranges have several wind gaps and streams crossing the various blocks. These are potential passages for wind transported material into the outer fringe areas, in the direction of the prevailing wind pattern.

5. In a terrain with evaporation in excess of precipitation, the presence of inland basins/depressions with centripetal drainage and lack of flushing system, help in accumulation of the saline material in the entire catchment, one of the major attributes of desertic areas.

6. The hydrogeological situation in the tract, as revealed in the Geohydrological map and by the work of the various agencies, is one of restricted aquifers often with brackish or saline water, with boundary condition and deep water tables. Recharge facilities are limited due to the low precipitation even in the fresh water aquifers (Lathi, etc.). This seriously hampers exploitation possibilities, recuperation of aquifers and maintenance of the ground water regime.

7. Due to a combination of climatic and geomorphic factors there is hardly any surface water system with integrated drainage and appreciable discharge in this zone, for the greater part of the

year. The only exception is the Luni and its tributaries, which too is, at present a misfit system, disorganized and without any major sustained flow for most months of the year.

8. The extensive salt Ranns of Kutch, into which the Luni discharges, also contributes to the salinity of the tract.

(e) Soil Characteristics

Two major factors in the pedological character of the arid zone have significant contributions to its desertification and lack of adequate vegetal growth. These are:-

1. In-adequate organic accumulation in the soils, due to the prevalence of a climate unfavourable to vegetal growth, not only during the current arid pahse, but from the previous extensive phase of aridity. As a result, the soils, even in the eastern tracts of the semi arid zone manifest limited soil profile development, often on ancient stablished dunes. The relatively richer soils are restricted to the fluvial margings and flood plains.

2. Well developed caliche formations (calcium carbonate material) in the solid profile, to variable depths in the region, with considerable consolidation, inhibits normal root and vegetal growth.

Apart from these basic pedogenic limitations, the intrinsic climatic conditions that promote erosion and wind transport, constantly remove the surficial layers of the soil cover, resulting in improverishment of plant growth environment. The movement of salinized water in some areas, and the deep water tables in many other tracts, are also deterrents to soil productivity.

IV BIOTIC FACTORS

The parameters listed in the preceding portions of this report indicate that the Indian arid zone is climatologically and in its other natural conditions a marginal zone, with a very delicate natural dynamic equilibrium liable to be upset by the slightest fluctuations of natural conditions. Super-imposed on this over all picture is the emergence of Man during the Early Quaternary era, almost simultaneously with the occurrence of the first arid phase in the Quaternary geological epoch. Since then, throughout the recent geological eras, the role of Man has been increasing in extent and degree in the entire tract, introducing anthropocentric activities that have definitely affected the dynamic equilibrium of the Indian arid tract.

The manifestations of deterioration in the desert areas and its adjacent semiarid fringe zone can be placed in two broad categories, viz. (a) problems and evidences within the arid zone and (b) manifestations of mobile sands and erosion outside the climatic boundary of the arid zone. However, both are linked up, since one leads to the other. Field observations, studies and experiences of various agencies, have led to a clarification of the situation, which now needs monitoring and quantification. The main biotic factors are being enumerated briefly:

(a) Demographic Factor

Successive decennial census reports have revealed an alarming growth of human population in the tract from 3.567 millions in 1901 to 10.236 millions in 1971. There has also been a simultaneous rise in the number of livestock (from 10.27 millions in 1951 to 16.44 millions in 1971) which is even greater than the human population. This has led to an adverse environmental situation, enumerated as follows: (a) reduction of the man : land and livestock : land ratio in the tract which is even normally devoid of adequate natural sustenance. The land per household has reduced from 17.77 ha in 1951 to 12.40 in 1971, with only 7.52 ha likely to be available at the turn of the century. There is a corresponding shrinkage in cultivable land; (b) rise in net sown area from about 28% in 1951 to 45% in 1971, with double cropped are arising from 0.4 to 1.45%. This has directly led to a shrinkage of lands normally used and suitable for grazing, with drastic removal of vegetal cover; (c) overdependence on agriculture lends to land degradation due to nonavailability of adequate cultivable land; (d) urbanization and industrialization have further aggrevate the Man: Land situation and reduction of forests for fuel and housing.

(b) Landuse Changes

Due to increased population and livestock pressure, vast areas of the arid zone have been brought under cultivation, often extending to marginal lands, pediment slopes of the Aravallis and other fringe areas where the natural conditions do not warrant farming. This also include areas of stabilised dunes, where farming and removal of roots and stubbles after cropping, has led to accelerated wind erosion. Increase in the livestock (particularly goats & sheep) have resulted in further depletion of vegetal cover. Coupled with the conversion of grazing lands to farming the region is undergoing an aggrevation of desertification through erosion on bare lands and aeolian shifting of particles and soil.

Introduction of irrigated agriculture in many areas without adequate drainage measures, have also given rise to accumulation of minerals and salts in the soil and near surface formations, in a tract with naturally impeded drainage and heavily charged with minerals/salts. In some locations, there has been rise of water tables to undersirable levels, with simultaneous increase of salinity and deterioration of the soil regime. All these factors have led to diminishing returns from the land, and enhancement of the desertic conditions.

New settlements, often on stabilised dune areas, urbanization, construction of roads, rail tracks, canals, without regard to the geomorphic units (stable dunes etc.) have led to rapid mobilisation of stable sand belts and consequent desertification by removal of vegetal cover and wind action. As such, throughout the arid tracts, settlements and human construcare are the zones or centres of sand mobilizations and movement. This is rendered more acute by overgrazing and felling of trees for fuels.

Along the Luni riverine zone, there are several serious manifestations of regime deterioration, in the form of salinisation of soil and water, development of negative gradients, particularly where dams have been constructed for storing and withdrawal of water. In many cases, withdrawal of water has led to lowering of water tables below an optimum depth, with resultant dessication and deflation. The Luni tract from Pichiak to Dunara is a classical example of salinisation of fresh water and loss of land productivity.

In the eastern fringe of the arid zone, in the districts of Churu, Sikar and Jhunjhunu, there are evidences of widespread mobilization of stable sand dunes, as a result of human interference (example near Sridungargarh Sikar etc.), leading to the creation of source areas for materials which are easily transported across the arid zone boundary east and north east wards into the Haryana, Punjab region or through the windgaps in the Aravallis. In fact, comparison of old topo-sheets have indicated increase of sand in some semiarid areas of eastern Rajasthan including Alwar, Jaipur and Tonk districts.

Geomorphological mapping in the eastern semi arid fringe and along the Aravallis, have indicated the presence of large sand deposits flanking both the windward and leeward sides. Recent studies also reveal increase in some of these deposits, near Saiwar and other locations, east of the Aravallis. Observations along the wind gaps (Pushkar, Tribeni and Sabi-sote) show shifts in sands and new accumulations.

Although such wind gaps are not extensive they are nevertheless helping in the funneling out of desert sands into the regions beyond, as a direct result of the deterioration of the conditions obtaining within the desert. Much of this outer zone is basically stable dune territory of the earlier arid phase, where cultivation and human activities may lead to mobilisation and erosion. As has been experienced in other arid zones of the world, prolonged phases of drought may ultimately turn such sand accumlation in the frings areas into menacing sources of loose material that will cover the farmlands, under greater dessication and wind action during such periods.

The increased emphasis on the exploitation of minerals and rocks in the arid zone and its eastern fringe has led to extensive mining and quarrying, denudation of hill slopes, large scale loosening of rock faces all leading to conditions that aggrevate the processes of desertification.

As mentioned in the relevant paragraphs, the livestock pressure has led to overgrazing, deforestation and exploitation of the woody biomass in the region.

This has resulted in extensive removal of vegetation, with consequent erosion hazards. Rodents have also contributed towards desertification.

In conclusions, it may be stressed that the Indian arid zone is, even under normal conditions, an area with a relatively greater population density, in comparsion with other arid regions. The intense biotic activities have logically led to over exploitation of the land and vegetation, triggering off a series of natural processes that are rapidly enhacing the physical manifestations of desertification.

V POSSIBLE EXPANSION OF THE INDIAN DESERT

The possible expansion of the Indian desert over the years has been studied through a series of maps prepared on the basis of geomorphic and other physiographic features. The problem has also be examined through quantitative comparisons of economic parameters like land use, water availability and crop yield performances between desert areas and bordering regions. All available evidences suggest that the Rajasthan desert, has not, and is not, advancing towards the east, but that fresh sand deposition is still going on and, towards the west, the desertic conditions have further deteriorated in the recent past (Sen and Mann, 1977).

(a) An assessment of environmental degradation in the arid zone

The inherent vulnerability of the land use intense biotic pressure have combined to set in a process of deteriotion within the arid zone. Different mainfestations of this process were quantified in respect of a 2,000sq.km.area has a case study for presentation at the UN Conference of Desertification in 1977. Besides this detailed study, a generalised map showing the vulnerability of different regions to desertification has also been prepared for the whole of Rajasthan. Presently, various critical indicators are being tests by the Institute as a part of desertification monitoring programme. (Sankarnarayn 1984).

About 23,882 sq.km. of area in Rajasthan has been affected by desertification hazards. About 4.34 per cent of this area has "already been affected" by desertification hazards. This unit is mostly concentrated in the extreme west in Jaisalmer. The dominant process of desertification here is the expansion of sand covers, dunes and shifting sand by wind erosion. Other dominant and associated processes are superficial concentration of stones or desert pavement by deflation, enlargement of salted or alkalinised areas without vegetation. Control of hazard is possible by irrigation, shelter belt, wind breaks, and sand dune fixation.

About 76.15 per cent of the total area of the desert is high to medium vulnerable to desertification process. Dune, shifting sand, wind erosion are the dominant process. The unit is concentrated along a belt in Ganganagar, Churu Bikaner, Jaisalmer, Barmer, Jodhpur, Jalore, Jhunjhunu and Nagaur districts. In several areas of hazard control is possible by means of irrigation and fresh water exploitation.

Only 19.50 per cent of the total desert area is subjected to "medium to light vulnerable" by desertification hazard. The dominant processes are water erosion, enlargement of rock out crops or indurated horizon in surface by water erosion. Dunes and shifting sands are the other associated factors. The unit is concentrated mostly along the eastern part in a direction of N.E. to S.W. parallel along the foothill of the Aravallis. Control of hazard is possible by exploiting ground water irrigation and soil conservation measures.

The intensity of desertification hazard in western Rajasthan is presented in Table 1(CAZRI, 1983)

After considering the geographic and climatic aspects and through quantitative comparison of physical and socio- economicc parameters, the problems on the possible expansion of the Indian desert towards the east of the Aravallis have been examined by the scientists of CAZARI since 1960. The inherent vulnerability of the land and intense biotic pressure (along with human land use system or adaptation) have combined to set in a process of desertification hazards leading to environmental degradation or deterioration of the Indian desert. There is an unanimity with regard to the deterioration of desert due to desertification process by human and other biotic interferences which need careful considerations. Some of these biotic interferences causing desertification processes that lead to the accentuation and deterioration of environment in western Rajasthan is described in this chapter.(Shankarnarayan, 1984).

VI INDICATORS AND ASSESSMENT OF DESERTIFICATION

Despite prodigious efforts made in reccent years by Government and international agencies both to control desertification and raise consciousness of it, there still remains considerable doubt about its nature, its extent and its relationship with other phenomena. Although technology and expertise are available for the treatment of the acknowledged causes of desertification it is rare that the treatment is successfully carried out. The most obvious reason for the failure is that the problems are often treated in piecemeal. What is needed is an integrated or multidisciplinary approach to treat the problems. Because when people are mainly responsible for desertification it can be most efficiently combated by diagnosing and arresting the physical and socio-economic processes that lead to it. Therefore, it is necessary to define an intergrated set of critical indicators that would diagnose and could assist in carrying out effective curative programme. These indicators when refined through field testing will enable to coordinate desertification programmes. Central Arid Zone Research Institute has identified three major groups of critical indicators which include micro indicators which need considerations. Once the the cause is identified it may not be difficult to cure the same. The indicators identified are:

1. Physical indicators:

(a) degree of salinisation and alkalinization; (b) depth and quality of ground water (c) effective soil depth; (d) dust storms and sand storms and dust collection (e) presence of soil crusts and amount of soil organic matter (f) change in water flow and

Table 1 : **Intensity of desertification in western Rajasthan**

S. No.	Units	Area in sq. kms.	percent of total area of western Rajasthan
	Desert and subdesertic zones		
1.	Desert	9290.00	4.35
2.	Arid zone	134552.00	62.88
3.	Semi arid zone	66830.00	31.25
4.	Sub humid zone	1100.00	0.53
5.	Humid zone	2110.00	0.99
	Total :	213882.00	100.00
	Natural vulnerability		
1.	Desert	9290.00	4.35
2.	High to medium vulnerable	162900.00	76.15
3.	Medium to slight vulnerable	41692.00	19.50
	Total :	213882.00	100.00
	Desertification hazards		
1.	Desertified area	9290.00	4.35
2.	High	135292.00	63.26
3.	Medium	67400.00	31.51
4.	Slight	1900.00	0.88
	Total :	213882.00	100.00

sediment flow in water courses (g) area covered by turgidity (h) change of weather and climate (i) movement of sand and piling of sandy hummocks (j) abandonment of using well.

2. The biological / agricultural indicators :

(a) Vegetation-canopy cover, above ground biomass : distribution and frequency of key species.

(b) Animal-key species and population of domestic species; hard compositions; production; abundance and frequency of the activities of the species leading to soil erosion and degradation.

(c) Yield (harvest)-trend of low production.

3. The social indicators:

(a) Irrigated farming; (b) dry land, (c) cultivation of marginal and long fallow lands (d) pastoralism (e) indiscriminate cutting of trees and deforestation, (f) mining, (g) tourism and recreational use (h) expansion, abandonment and desertification of settlements, (i) Urbanism and compact settlement, (j) Nomadism (k) population structure-migration.

To identify the indicators in order to visualise the presence of desertification problem observations to be recorded by the specilalists or farmers are:

1) Movement of sand-direction and speed.
2) Deflation of fine material-increase in coarse materials.
3) Degradation of marginal lands-removal of top soil and grass cover.
4) Sand accumulation.
5) Increase of agricultural land.
6) Enlargement of rock outcrops- degre of erosion.
7) Enlargement of bare areas because of sealing of soil surface.
8) Decreasing or disappearance of vegetative cover
9) Increased salinity-appearance of halophytic species, yellowing of crops, saline crust on surface. Increase of salinity in ground or drainage water or brackish water,
10) Seepage.
11) Rise or lowering of water table-stagnation

of waters-increase of waterlogged areas

12) Development of rills, gullies and badland topography.
13) Drying up of soil.
14) Degradation of vegetation.
15) Enlargement of rangeland and increase in cattle population.
16) Lowering of the crop yield and fodder crops.
17) Change in the water balance.
18) Frequency of dust storms.
19) Frequency of drough-failure of rains.
20) Migration.
21) Low frequency of settlements.

VII SOCIOLOGICAL CONSTRAINTS AND INNOVATIONS IN COMBATING DESERTIFICATION.

If action programe are to be successful, they must be relevant to the issues and the people they are designed to help. For the problems of desertification-the social economic, legal, political and environmental aspects are so interwined that nothing but an integrated approach to action can be seriously considered. In all these efforts, it is the people's perticipation that constitutes the *sine-que-non* for success. Keeping these in view and based on technologies developed by CAZRI, the Government of Rajasthan revitalised the Desert Development Board and establishad a Department of Afforestation and Pasture Development at Jodhpur in 1978. The major components of this revegetational programme and achievements till 1983-84 are given in Table 2.

Table 2: **Statement showing schemewise area covered under afforestation and pasture development works in western Rajasthan (from 1978-79 to 1983-84).**

Name of Scheme	Unit	Area covered from 1978-79 to 1983-84					
		Under Desert development programme	Under drought prone area programme	Total (3+4)	Under World Bank Project Rajasthan Canal Project area	Under World Food Programme	Grand Total
1. Silvi pastoral and mixed plantation	Hect.	12868	-	12868	-	-	12868
2. Sand dune stabilisation & pasture development.	Hect.	11953	11650	23603	38380	4000	65983
3. Village fuel wood and fodder plantation.	Hect.	7128	456	7584	1715	120	9419
4. Rehabilitation of degraded forests.	Hect.	4350	1400	5750	-	-	5750
5. Canal side plantation	Hect.	375	1725	2100	5620	200	7920
6. Plantation on sheep pasture plots.	Hect.	532	450	982	-	-	982
7. Roadside plantation	RKm.	10848	30	10878	2976	14	13868
8. Farm forestry (plants distributed to farmers)	Plants in lacs	24.82	-	24.82	57.50	-	82.32
9. Grass collection	Qty.in thousand Qtls.	104	-	104	-	-	104
10. Pasture Dev. & plantation in irrigated area of Left Bank of RCP area.	Hect.	1400	-	1400	-	-	1400

(Since 1982-83 D.P.A.P. has been merged with D.D.P. and Rajasthan canal

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3

ECOLOGICAL IMBALANCE AND FOOD SYSTEM WITH SPECIAL REFERENCE TO INDIA

Mohammad Shafi

I INTRODUCTION

I wish to begin my discourse on 'Ecological imbalnce and Food Systems' by making a reference to the United Nations Conference on Desertification which was held in last August early September 1977, in Nairobi, Kenya. It was a comprehensive, scientific and sociopolitical forum. About 100 countries and 80 inter-governmental and nongovernmental organizations sent their scientists/engineers to attend this conference. Altogether some 1500 persons participated in this conference.

Why was this conference held.? The sub-tropical, zone of the Sahara, consisting of many countries like the Senegal, Mali, Mauretania, Upper Volta, Niger, Chad, parts of Sudan, collectively known as Sahel, was in the grip of a severe drought from 1968-73. In Sudan 15 percent of the north and central parts have been severely desertified while 30 percent is moderately affected. The water surface area of the Chad lake has declined to twothirds of its normal size, while the African rivers the Niger and the Sanegal, completely ceased to flood during the high water season, and very large number of wells supplying drinking water were depleted, and surface reserviors normally accumulating rain water vanishad completely. Livestocks died in large numbers and crops failed and this affected the food supply seriously. It is estimated that about 250,000 persons of the Sahel zone died from famine.

In fact the Sahara desert is moving southward at an accelerated rate all along the 5,600 kms. southern fringe from Senegal to N Ethiopia. The southward march of the desert is at the rate of about 48 kms. per year. Why such situation has arisen.? It is largely because of environmental hazards of desertification in this region. Overgrazing of the rangelands, severe depletion of top soil cover, serious erosion problems owing to deforestation, and misuse of crop lands as a result of bad land management are the chief causes. It is estimated that the rate at which lands are withdrawn from agriculture as a result of desertification is nearly 50 thousand sq. km. per year. The gravity of the situation can best be realized by appreciating the fact that the total area of potentially productive arid land threatened by desertification in the world is 45 million sq. km. which currently sustains 600-700 million persons. The International Geographical Union is also active to the problem and appointed working group on Desertification in and around arid lands under the Chairmanship of Prof. Mabbutt who is also project-coordinator of UN University Arid Lands sub-programme. The working group held its meeting at Tuscon. (Arizona) from 3 to 8 January 1979.

Desertification has been defined as a long term decline in the land's biological productivity. In some quarters this is considered to be too general a definition. It has been redefined as-Desertification represents a process leading to a declined in biological activity and to a consequent reduction in plant and biomass in relation to the land's carrying capacity for livestock, crop yields, and human well-being.

Even this definition does not take cognisance of the population growth and corresponding increase in needs, the means of transport, proper storage facilities and distribution of food grains and the environmental hazards such as droughts. The definition of desertification has been modified as 'Desertification is a problem of interaction between complex and unstable environments of arid territories used and inhabited by human population that results from their attemps to provide means of existence'. While failure of rainfall is an important factor accentuating the process of desertification, the social and economic factors are nonetheless important. It may be pointed out that some modern ecologist use the word desertization instead of desertification. International Organizations like FAO, UNESCO, International livestock centre for Africa (ILCA), UNEP have also used this term. Desertization has been defined as the extension of typical desert landscaps and landforms to areas where they did not occur in the recent past. The process takes place in arid zone bordering the deserts under the average annual rainfall of 100 to 200 mm. with outside limits of 50 to 300 mm. However in this paper a broader view has been taken and desertification includes desertization.

In India there are hot arid, semiarid and dry/sub humid regions. The hot arid areas comprise the desert zone of western Rajasthan, parts of Gujrat and Haryana. The semi arid and dry sub humid areas are found in eastern Rajasthan, Andhra Pradesh, Maharashtra, Gujrat, Karnataka and Tamil Nadu. Most of the districts in these areas and particularly those of western Rajasthan face great instability in production due to erratic and inadequate rainfall.

The hot arid lands are faced with real problem: hot desicating winds, shifting sand dunes, absence of streams, saline ground water, poor vegetation, cultivation of marginal lands and the destruction of marginal lands and the destruction of stunted trees for fuel wood. The National Commission on Indian Agriculture has recommended a 15 year comprehensive and integrated programme for the improvement and economic development of hot arid lands. It recommends a simultaneous attention to the development of a/water resources. b/forestry. c/animal husbandry and d/ pastures. The Indira Gandhi Canal (formerly Rajasthan canal project) has been recommended to be recast to exclude unsuitable areas where the cost of land levelling and development will be high and to construct five left canals to take some water deeper into the desert with a view to bringing more areas under irrigation. Apart from this, suitable water conservation techniques like *khadin* and bandh should be adopted on a large scale.

Large scale tree plantation with the help of canal water is of the highest importance. The raising of shelter belts and wind breaks will go a long way in arresting wind erosion and stabilizing sand duens. The effect of sand casting on arable fields will be minimised and the green belt will also reduce the desicating effect of hot winds on crops. Such tree plantation will also meet the requirements of fuel wood and small timber and prevent overexploitation of the available vegetation resources and the digging of roots of bushes which is leading to degradation of the desert by loosening the soil and resulting in sand blowing.

More than one and a half million drought resistant trees including neem and ber have been planted by the Ecological Task Force. This has helped to large extent in preventing the fury of the desert sand dunes. A massive afforestation and pasture development drive has also been initiated near Bikaner and a sum of Rs. 500 millions will be spent in 10 years for growing vegetable on 50,000 hectares of arid land with the help of the canal water.

In order to halt the process of desertification the following measures will be most benefical a/ introduction of social forestry (b) pasture development, and animal hasbandry c/the development of horticulture.

II Afforestation

There has been a considerable deforestation on the hills and uplands for timber and fuel. This has resulted in serious soil erosion and has adversely affected crop production on the hills and uplands. The accelerating degradation of woodland throughout Africa, Asia and Latin America, caused in part, for fuel gathering is the most profound ecological challenge of the 20th century and ecological threat to human will-being is far more insidious and intractable than the industrial pollution of air and water as the former undermines the productivity of the land through soil erosion, floods, creeping deserts and declining soil fertility. All these problems are accentuated by deforestation as land is cleared for agriculture and as rising population continues, its search for fuel-wood increases.

Besides, afforestation will help sand dune stablization, serve as shelter belts and wind break. Unstablized sand dunes shift their location and encroach upon roads, railway lines, irrigation canals and the sand covers the plant and cultivated fields, CAZRI has evolved techniques for stablization of sand dunes. The benefit cost ratio for sand dune stablization technology is about 1:3.58. The return starts accruing after an initial period of 5-10 years. In the farming ecosystem in the arid region, agriculture has to be combined with forestry in order to impart stability and generate income. Afforestation on the hills and uplands will not only prevent soil erosion but also meet the need of people in respecct of timber and fuel.

III Pasture development

In the arid and semi arid lands, where land is not suitable for cultivation, the meagre water facility should be utilized either for tree plantations or for pasture development. Such a grass cover will not only increase the supply of fodder, but also provide a cover to land which is subject to soil and water erosion. The existing pasture should be protected from overgrazing. There is considerable scope for pasture development both in the arid and semi-arid areas. In western Rajasthan the soil is reasonably fertile but owing to lack of water it cannot be devoted to crop cultivation. These are the potential lands for pasture development. The dune flanks, piedmont slopes and other areas of shallow soils should be devoted to a permanent cover.

IV Suitable change in cropping patter

Cropping patterns are to be evolved on the basis of dryland farming and this would require appropriate varieties of crops, economical use of water, increase in the croping intensity through inter-cropping. The most important aspect is the preventation of loss of moisture from the soil and in this respect mulching is very important. There are different kind of mulches: organic mulches, plastic mulches, gravel and soil mulches. Perhaps the most important type of mulch in the arid lands could be soil or dust mulch created by stirning the surface of the soil to keep it loose and absorb rain water during the cropping season. Such a mulch would decrease evaporation and permit infiltration and at the same time shall be economical. Mulching and water harvesting, afforestation and pasture development with suitable cropping pattern are the important measures which will check the process of desertification. However it is necessary that plans of action should be formulated rather than future research

V DEVELOPMENT OF HORTICULTURE

The arid environment with its brackish water is quite suitable for such fruit trees as date palm, *ber,* (Zizyphus) pomegranate, guava and custard apple. The districts of Jaisalmer, Barmer and Bikaner are well suited for the production of dates in India. Besides the *Khadins* in Jaisalmer which are low lying basins collecting runoff from surrounding catchments, make the cultivation of some hardy fruits possible. CAZRI has standardized the whole technology of *ber* cultivation under rain fed and irrigated conditions. The per tree yield under rainfed condition on an average is about 50 to 60 kg. and under irrigated condition it is almost double this average. The net profit (according to the report of the working group on Arid zone Research conducted by DST) is Rs. 1425 per/ha in the third year to as high as Rs. 28000/ha in the tenth year.

The life span of per orchard is 45 to 50 years. Similarly the income from dates is Rs. 2300/ha from third year onwards and attains as high as 17000/in the 9th or 10th year.

It would be worthwhile to say a word here about post harvest technology relating to the storage of the farm produce. when there is a large produce of ber, arrangements should be made to transport it to distant market and as the sheaf life is hardly one weak, high density polythene packing and research in storage for preservation, would be useful. The processes for the manufacture of jam, squash evolved by CAZRI should be made popular. This will strengthen the economic base of the people of the arid region.

It is of the highest importance to establish a regular monitoring base of the state of ecosystem of the arid territories in order to anticipate desertification processes and identify the region in which they are taking place. For, the arid and semi arid areas of the country an arid surveillance should be carried out in which data could be quickly analysed and suitable steps could be taken whenever needed. One effective step as a result of such monitoring could be to prepare maps showing types of desertification. Later plans should be formulated to combat desertification in accordance with plans envisaging improvements in land use. The LANDSAT imagery with its advantages of multispectral sensing and repetitive coverage can be of great help in monitoring desertification. Among the indicators of desertification listed by the United Nation Conference on Desertification (UNCOD), the following can be determined from the earth resource satellite data:

a/ distribution of vegetation and soil.
b/ movement of sand dunes.
c/ extent of agricultural areas.
d/ extent of surface water resources.
e/ distribution of bare ground.

The progress of desertification can be determined by the distributions and the relationship to each other of these indicators, if continnous observation are made over a period of time and recorded on thematic maps.

An international project is also being sponsored on the development of melthodologies for assessing desertification on the basis of selected indicators by the UN and for mapping desertification by FAO in close association with the organization of International Map of Soil Degradation. While all this is being done, it is better to echo with the recommendation of the United Nations conference on desertification. "Action must not await complete knowledge about complex situation. The existing knowledge should be applied not only to stop the physical processes of desertification, but also to educate people in minimizing the harm done to the fragile ecosystems of drylands by existing economic and social activities."

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4

REMOTE SENSING IN MONITORING DESERTIFICATION PROCESSES UNDER DIFFERENT LANDFORMS (ECOSYSTEMS) OF THE INDIAN DESERT

Surendra Singh

I INTRODUCTION

The Indian desert occupies an area of 3.2 lakh sq. km; the bulk of the area 1,96,150 sq.km (61%) lies in the Rajasthan desert. In this desert, several fluvial and aeolian landforms (ecosystems) created by different geomorphic processes under wet and dry climatic phases, have been identified. In the recent decades, the increasing human and livestock population pressure has disturbed the ecological balance of the fragile ecosystems, resulting into the acceleration of the desertification processes responsible for the degradation of the different ecosystems are water erosion, wind erosion/deposition, salinity/alkalinity, flood and pollution.

In order to monitor the accelerated desertification processes, the systematic studies on these processes by employing advanced remote sensing techniques will be of paramount importance. Remote sensing is a recording device for the acquisition of information of an object or phenomena with out coming in physical contact of the object or phenomena under study. The studies of the desertification processes through conventional methods will be more costly and time consuming and the temporal changes in the ecosystems could not be monitored. Remote sensing techniques have been found an important tool in monitoring desertification processes by several workers (Worcester and Dalsted, 1978; Myers, 1979; Reining, 1979, Abdel Hady et al; 1979; Ghose et al; 1977 Singh et al; 1978 & 1983).

Keeping in view the significance of the environmental studies in the development planning of the arid regions, the studies on the monitoring of natural resources and desertification processes by employing remote sensing techniques in conjunction with ground truth were conducted in different parts of the Indian desert. The salient findings of these studies have been presented in this paper.

II METHODOLOGY

Studies on the desertification processes under different landforms (ecosystems) were done with the help of aerial photographs of 1:25,000 and 1:40,000 scales. Landsat imageries of 1:500,000 and 250.000 scales, S.O.I. toposheets of 1:50,000 and 1: 126,728 scales and field surveys. Based on these observations, the boundaries of different landforms (ecosystems) were delineated and mapped. The morphologial changes in these ecosystems resulted due to various desertification process like water erosion, wind erosion/deposition, salinity, and floods were recorded and mapped. The vertical and horizontal extent of the hazards created by the accelerated desertification processes in different ecosystems were measured in the field and laboratory. The comparative information on these morphological changes under different ecosystems were also collected from the toposheets of the year 1934, aerial photographs of 1958, Landsat imageries of 1977 and the recent field surveys.

III RESULTS AND DISCUSSION

1. Geomorphic Evolution and Characteristics of the Ecosystems

In the Indian desert, fluvial and aeolian ecosystems have been created by fluvial and aeolian geomorphic processes under different climatic phases during the Quaternary period. Fluvial ecosystems were formed under two prolonged wet phases which prevailed, probably, during the Pleistocene and early Holocene period. The fluvial desert ecosystems constitue hills, rocky pediments, flat buried pediments vast flat aggraded older alluvial plains. The aeolian desert ecosystems created under two prolonged dry phases of probably pre-Holocene and late Holocene periods are sand dunes, sandy undulating inter-dune and aggraded older alluvial plains, flat deep sandy aggraded older alluvial plains and sandy undulating buried pediments. These fluvial and aeolian ecosystems have different morphological characteristics which have been presented in Table 1.

2. Desertification and Ecosystems

The definitions of desertification are legion but from geomorphic point of view the desertification could be classified into two types viz; 'climatic' and 'biotic'. The processes of desertification resulting from the changes in climate can be termed as 'climatic desertification'. The desertification processes resulting into the deterioration of the fragile desert ecosystems due to increasing biotic activities could be termed as 'biotic desertification'.

Desertificcation in its simplest form is a depletion of the biological productivity of arid and semi-arid lands.

Dregne 1977 has stated that as desertification continues, the ecosystems regresses resulting in

323
49168

Table 1. **Salient morphological characteristics of the fluvial/aeolian ecosystems in the Indian desert**

S.No.	Fluvial/aeolian ecosystems	Hypsometry in metre (a.g.1)	Average slope (in degree)	Sediment characteristics	Drainage characteristics	Area in hectares
1.	Hills	90-100	15-35	Deposits of sand, gravels and cobbles in the form of talus, size 2-64 mm and depth 25-80 cm.	Numerous channels, radial, parallel and dendritic patterns	57540
2.	piedmont plains	10-20	Upper part 5-8 Lower part 3-5	Colluvial and alluvial deposits of 2-4 mm size and 500-200 cm depth	Deep to very deep channels of 2 to 5 m depth, 4 to 10m width and dendritic pattern	88910
3.	Rocky/gravelly pediments	5-6	2-3	Gravels and sand of 2-4 mm size and 5.20 cm depth	0.42 m deep channels, dendritic and radial patterns.	78890
4.	Flat buried pediments	6-8	1-3	Alluvial sediments varying from loamy sand to sandy loam and loam of 0.06-0.85 mm size and 10 -30 cm depth	1-2 m deep channels, widely spaced and froms dendritic and parallel patterns	86730
5	Flat aggraded older alluvial plains	1-2	0.5-1	Alluvial sediments, varying from sand to loamy sand and sandy loam to clay loam of 0.06-0.83 mm size and 7-180 cm depth, underlain by hard kankar pan	Truncated and obliterated channels Sheet flow dominant and at certain places, impeded drainage conditions have developed	687400
6.	Flat inter-dune plains	1-2	0.6-1.5	Alluvial sediments varying from sand to loamy sand, loam & clay loam of 0.06-1.19 mm size and 10-200 cm depth underlain by hard kankar pan	Short and obliterated channels, widely spaced and impeded at places	25850

S.No	*Fluvial/aeolian ecosystems*	*Hypsometry in metre (a.g.l.)*	*Average slope (in degree)*	*Sediment characteristics*	*Drainage characteristics*	*Area in hectares*
7.	Graded river beds and younger alluvial plains	0.75-1& 1-1.5	1-2	Alluvial sediments varying from coarse sands to gravelly sands and sand to loamy sand of 0.06-2 mm size and 1000-2000 cm depth	Short channels, parallel to sub-parallel drainage patterns, the Luni and its tributaries form the major drainage system	214010
8.	Sand dunes	10-60	Leeward-20 Windward-3-4,Flanks 8-12	Compact and loose aeolian fine sand of 0.06-0.25 mm size and 1000-6000 cm thickness	Surface drainage absent except some short channels developed due to fluvial dissections	147450
9.	Sandy undulting interdune plains	1-3 and 3-5	Irregular 1-2 and 2-3	Aeolian fine sands in the form of sheets of 100-400 cm thickness and hummocks of 1 to 4 m height and sand to loamy sand and sandy loam sediments of 0.6-0.59 mm size	Surface drainage absent except few short relics of old channels	96740
10.	Sandy undulating aggraded older alluvial plains	4-6	1-3	As above	Surface drainage absent but short channels between undulations present	164970
11.	Sandy undulting buried pediments	10-40	2-3	Aeolian sediments of 0.06 to 0.25 mm size and 200-400 cm thickness in the form of sand dunes of 2-10 m and 10-40 m height underlain by alluvial sediments and solid rock	Deep to very deep channels of 3-10 m depth and 5-20 m width forming dendritic and radial patterns	7010

decreased biomass in desired grazing species, invasion by unfavourable species, increased susceptibility to soil erosion and poor living conditions for humans.

Geomorphologically the term desertification refers to the deterioration of fragile ecosystems which are beyond their carrying capacity for sustained production by cultivators, herdsmen and others. In other words, increasing biotic activities in combination with drought accelerate the deterioration of the fragile ecosystems and lead to desertification. The term ecosystem according to Tansley (1955) includes not only the organism complex but also the whole complex of the physical factors forming what we call the environment of the bioms-the habitat factors in the widest sense.

The ecosystems thus can be defined combination of abiotic physico-chemical environment and the biotic assemblage of plants, animals and microbes.

Based on the above definition, several fluvial and aeolian ecosystems have been identified in the Indian desert. The ecosystems have been degraded by the different desertification processes, resulting into the depletion and deterioration of their physical and biological properties. Desertification processes and their impact on different fluvial and aeolian ecosystems have been discussed below.

(a) Desertification of the Fluvial Ecosystems

Man's interference with the fluvial ecosystems of the Central Luni basin and the Jodhpur district, enhanced the fluvial geomorphic processes which created the sheet, rill, gully, salinity, flood and pollution hazards of different intensities. The loss of the sediments from each ecosystem could not be estimated quantitatively but the extent of the areas affected under each ecosystem by the above accelerated fluvial hazards viz; water and salinity has been worked out and is presented in Tables 2 and 3. Fluvial ecosystems occupy 74.82% area in

Table 2. Areas affected by desertification processes under different ecosystems in central Luni basin

S.No.	Fluvial Ecosystems	Total area under each ecosystem (in hectares)	Extent of areas affected by fluvial hazards (in hectares) Sheet	Rill	Gully	Salinity	Aeolian ecosystems	Total. area under eacch eco-system (in hectares)	Extent of areas affected by aeolian and/or fluvial hazards (in hectares) wind erosion	wind deposition	wind deposition water erosion
1	2	3	4	5	6	7	8	9	10	11	12
1.	Hills	57.540 (3.48)	-	7.420 ((0.45)	5,012 (0.30)	- -	1. Sand dunes	1,47,450 (8.92)	3,720 (0.23)	39,990 (2.42)	12,270 (0.74)
2.	Piedmont plains	88,910 (5.38)		19,370 (1.17)	67,560 (4.09)	-	2. Sandy plains	96.740 (5.85)	8,040 (0.49)	73,280 (4.43)	15,420 (0.93)
3.	Rocky/gravelly pediments	78,390 (4.77)	18,180 (1.10)	15,350 (0.93)	35,050 (2.12)	-					
4.	Flat buried pediments	86,730 (5.25)	29,590 (1.79)	3,730 (0.23)	37,420 (2.26)	- -	3. Sandy Undulating aggraded older alluvial plains	1,64,970 (9.98)	3,770 (0.23)	120,110 (7.27)	7,460 (0.45)
5.	Flat aggraded older alluvial plains	6,84,700 (41.43)	5,955 (0.36)	7,500 (0.45)	-	47.190 (2.85)					
6.	Flat interdune plains	25,850 (1.56)	23,610 (1.42)	-	-	2,240 (0.14)					
7.	Graded river beds and younger alluvial plains	2,14,010 (12.95)	2,900 (0.18)	4,680 (0.28)	35,890 (2.17)	35,340 (2.14)	4. sandy undulating buried pediments	7,010 (0.43)		3,070 (0.19)	3,942 (0.24)
		12,36,630 (74.82)	80,235 (4.85)	58,050 (3.51)	1,80,932 (10.94)	84,770 (5.13)		4,16,170 (25.18)	15,530 (0.95)	2,36,450 (14.31)	39.090 (2.36)

Figures in parenthesis indicate percentage of the total area of the basin.

Table 3. Areas affected by desertification processes under different ecosystems in Jodhpur district

S.No.	Fluvial ecosystems	Total area under each ecosystem (in hectares)	Extent of the areas affected by fluvial hazards (in hectares)				S. No.	Aeolian ecosystems	Total area under each ecosystem	Extent of the areas affected by aeolian and/or fluvial hazards in hectares		
			sheet	Rill	Gully	Salinity				Wind erosion	Wind deposition	Wind deposition water erosion
1.	Hills	28,734 (1.26)		7,234 (0.32)	21,500 (0.94)	-	1	Sand dunes	3,05,931 (13.38)	80,000 (3.50)	2,00,000 (8.75)	25.931 (1.13)
2.	Piedmont plains	5,679 (0.25)		707 (0.03)	4,972 (0.22)	- -	2.	Sandy undulating interdune plains	1,54,926 (6.78)	50,026 (2.19)	80,000 (3.50)	24,900 (1.09)
3.	Rocky/gravelly pediments	1,44,672 (6.33)	9,613 (0.42)	5,014 (0.22)	1,30,045 (5.69)	-	3	Sandy undulating aggraded older alluvial plains	29,72,92 (13.03)	97,792 (4.28)	1,50,000 (6.56)	50,000 (2.19)
4.	Flat buried pediments	1,99,877 (8.74)	30,142 (1.32)	4,795 (0.21)	4,940 (0.22)		4	Flat deep sandy undulating aggraded older alluvial plains	2,94,731 (12.89)	94,731 (4.14)	2,00,000 (8.75)	
5.	Flat aggraded older alluvial plains	5,87,843 (25.71)	99.445 (4.35)	15.705 (0.69)	-	30,307 (1.33)						
6.	Flat interdune plains	98,657 (4,32)	17,756 (0.78)	6.365 (0.28)	4,942 (0.22)	5,025 (0.22)	5.	Sandy undulating buried pediments	1,00,277 (4.39)		60,000 (2.62)	40,277 (1.76)
7.	Graded river beds and younger alluvial plain	66,881 (2.92)	-	3,525 (0.15)	2,075 (0.09)	7,383 (0.32)						
		11,32,343 (49,53)	1,56,956 (6.87)	43,345 (1.90)	1,68,474 (7.37)	42,715 (1.87)			11,53,657 (50.47)	3,22,549 (14.12)	6,90,000 (30.18)	1,41,108 (6.17)

Figures in parenthesis indicate percentage of the total areas of the district.

the Central Luni basin and 29.80% of the total area of the basin has been desertified by sheet, rill, gully and salinity hazards. In Jodhpur district, 49.53% area is under fluvial ecosystems and 18.01% of the total area of the district has been affected by above hazards.

(i) WATER HAZARD : Sheet hadzard is mainly coffined to the rocky/gravelly pediments, flat buried pediments, flat aggraded older aluvial and interdune plains and the extent of this hazard under each ecosystem in above two regions has been given in Tables 2 and 3. The constant grazing and cultivation have destroyed the surface stability of these ecosystems and the sediments have been washed away by sheet flow and the kankar pan has exposed to the surface at certain places. This hazard has damaged 7.87% area in the Central Luni Basin and 6.87% in the Jodhpur district, resulting into the decrease of the biological productivity of these ecosystems.

The accelerated fluvial hazards have created new rills of 0.45 to 90 cm and 90 cm to 1 m depth and 1 to 3 m width and the gullies of 1 to 2 m and 2.5 to 3.5m depth and 3 to 4.5 m and 4 to 5.6 m width in the hills, piedmont plains and rocky/gravelly pediments. The flat buried pediments and flat aggraded older alluvial plains are mainly affected by widely spaced rill hazards of 30 to 75cm depth and 90 cm to 1.5 m width. The length and width of the existing rills and gullies under these ecosystems have also been increased by 0.5 to 1 m due to enhanced fluvial activities (plate 1) Rill and gully hazards nave turned into 'bad lands', 16.79% and 9.27% grazing and cultivated lands of these fluvial ecosystems in the Central Luni basin and Jodhpur district, respectively and their biological productivity has also decreased.

(ii) SALINITY HAZARD : It is largely concentrated in the flat aggraded older alluvial and interdune palins and younger alluvial plains and has reulted due to the construction of tanks and canals, damming of ephemeral rivers and irrigation by tanks and canals, such as Summair Sammand, Chopra and Parasla etc. In Jodhpur district, the construction of the tanks and canals accross the courses of the prior drainage channels, has resulted into water logging, capillary rise of the sub-surface salts and spread of salinity in the adjoining agricultural fields. The salinity hazard developed due to this process has damaged 2390 ha. of lands in the Luni block of Jodhpur district around Nimbla, Moklasni, Kharabera Bhiotan and between Lolawas and Bhetnada (Singh et al, 1978).

The salinity in the soil and ground water of the younger alluvial plains has also developed due to the construction of Jaswantsagar reservoir across the Luni river in the Jodhpur district during the year 1899. Due to the excess irrigation and seepage from this reservoir, the impeded drainage conditions were developed along the river in the younger alluvial plains and the water in the wells became saline in a period of less than 100 years. In the command area of Jaswantsagar reservoir, the irrigation by saline waters having 280 to 868 ppm total soluble salts has affected 6170 hectares cultivated land. In the central Luni basin, the contruction of Erinpura reservoir on the Khari river, Sardarsamand reservoir at the cconfluence of the Guhiya and the Sukri rivers, Kharda and Nayagaon tanks has resulted into drainage problems and desertification of younger alluvial flains (plate 2). The salinity of slight to moderate intensity has affected 934.3 sq. km. (6.96%) area of the saline older and younger alluvial plains in the Guhiya and the Bandi catchments. Moderate to evere salinity hazard has desertified 201.6 sq. km. (1.49%) area of the saline younger and older alluvial plains and flat buried pediments in the Bandi and the Luni catchments.

Severe to very severe salinity has degraded 111.9 sq. km. (0.84%) area of the saline older alluvial plains in the Luni and the Guhiya catchments. Mann and Chatterji (1978) have reported that four canal systems Viz, Bhakra canal, Gang canal, Chaggar flood water irrigation and Indira Gandhi canal in the western Rajasthan, 23460 sq. km. of the area is likely to develop salinity and drainage problems if the present rate of the rise of ground water level, 0.43 to 0.83 m per year continued. In the Indira Gandhi canal command area, due to the presence of impervious subsurface formations the water logging and salinity problems have developed in large acreage of sandy older alluvial plains, sand dunes and interdune plains (Plate 3).

(iii) FLOOD HAZARD : An unprecedented flood of July 1979 acting as a geomorphological agent caused conspicuous morphological changes in the rivers, flood plains, pediments and plateaus which in turn had affected the fertility status of the soil and landuse patterns of these landforms (ecosystems)

The turbulance flow and high velocity of flood waters due to the erosion and deposition proceses caused conspicuous morphological changes in the river beds and flood plains of the Luni and its tributaries. The prodigious reverine material brought by the flood waters resulted into the lateral accretion deposits in the form of sand bars and point bars of 1 to 1.5m height, 1.5 to 2m length and 0.75 cm to 1 m width within the beds of Luni and the Mitri rivers near Bhawi, Satlana, Dunara, Kosana and Bisalpur. The high discharge of flood waters and sediments resulted into the overbank flow and vertical accretion deposits over the flood plains in the form of sand sheets and sand mounds of different magnitude and shape. The sand sheets of 20 to 60 cm thickness and sand mounds and ridges of 1 to 2.5 m height, 120 to 200 m width and 150 -

to 750 m length have developed on the flood plains of the Luni, the Sukri and the Mitri rivers near Bala, Bhawi, Piplad Siyat, Pichak, Siyara, Pipar, Buchkala, Bislpur, Silor, Karmawas, Bamsin and Tilwara. The coarse sand deposits of slightly higher magnitude in the form of sand sheets of 40 to 110 cm thickness, sand mounds of 2 to 3.5 m height, 300 to 1200 m length and 250 to 450 m width had been deposited on the flood plains of the Luni river near Satlana and Dunara. The flood waters also dissected the flood plains of these rivers near Buchkla, Pipar, and Rajpuriya into the gullies of 2 to 3 m depth and 2.5 to 4.5 m width. These gullies have turned 30 to 40 per cent fertile agricultural lands of these flood plains into 'bad lands'. The interfluves in the upper parts of the pediments and plateaus near Bujwar, Hiradesar, Ransigaon and Berai were also dissected into gullies of 90 cm to 1.5 m depth and 1.5 to 3.5 m width. The morphological changes in the erosional and depositional forms resulted into the depletion of the biological productivity of the flood plains, pediments and plateaus. ((Plate 4).

The comparative study of the physical and fertility characteristics of the fresh coarse sediments and original buried soils of the flood plains from 39 sites revealed that there is a significant variation in the above characteristics of these two types of deposits. The fresh sediments are very light, loose, structureless sand and gravel but the original buried soils are light to dark grey and somewhat aggregated. The fresh sediments have 3 to 4 per cent clay and less than 1 per cent silt and around 3.5 per cent moisture retention capacity. The original soils under the fresh sediments are sand to loamy sand and sandy loam also containing 6 to 10 per cent clay and 4 to 7 per cent salts and 5 to 20 per cent moisture retention capacity (Dhir et al; 1982).

The results of the fertility status of the fresh sediments and original buried soils are presented in Table 4.

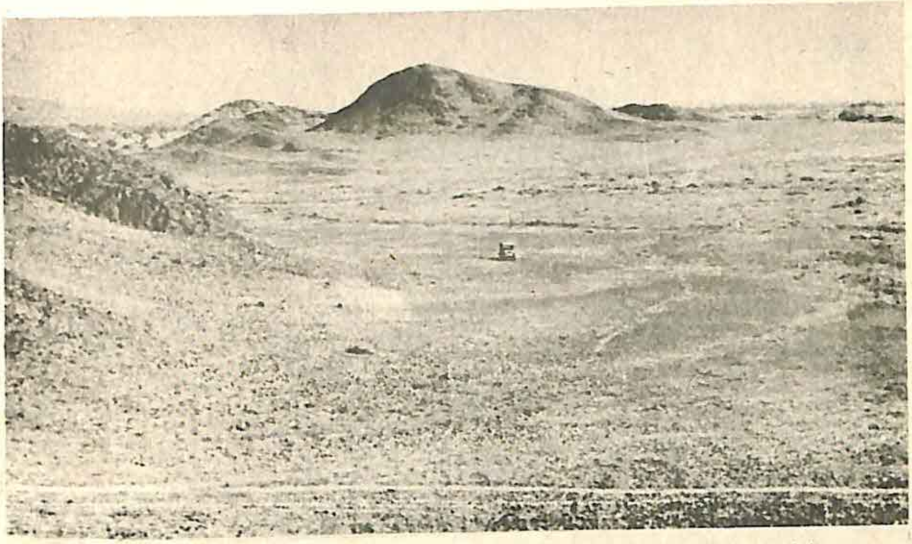

Plate. 1. Hills, rocky/gravelly and buried pediments desertified by sheet, rill and gully hazards.

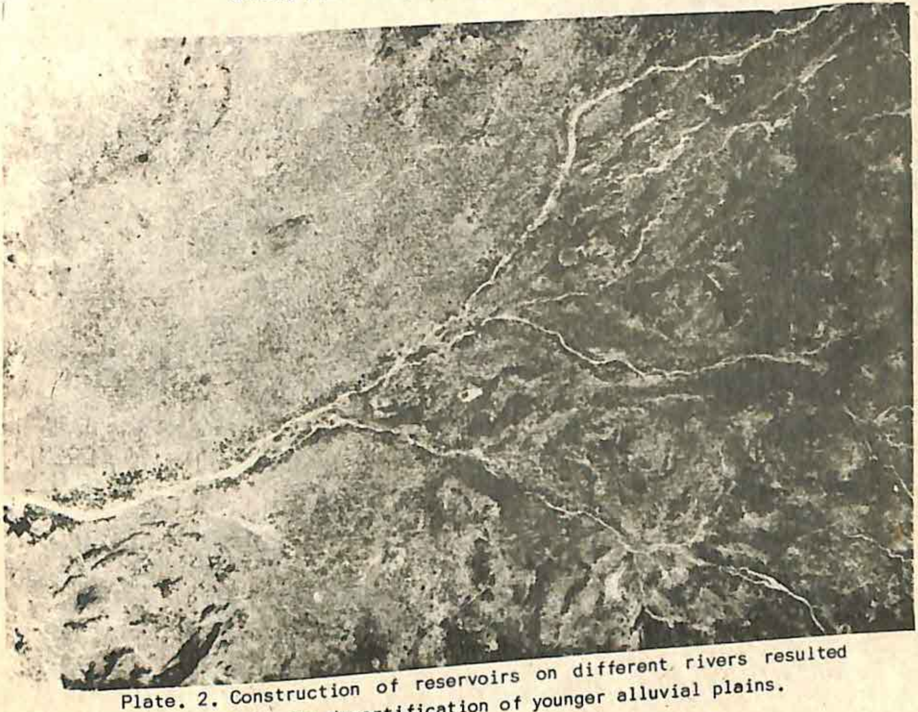

Plate. 2. Construction of reservoirs on different rivers resulted into the desertification of younger alluvial plains.

Plate. 3. Sandy older alluvial and interdune plains desertified by canal irrigation

Plate. 4. Flood plains and pediments desertified by flood hazards.

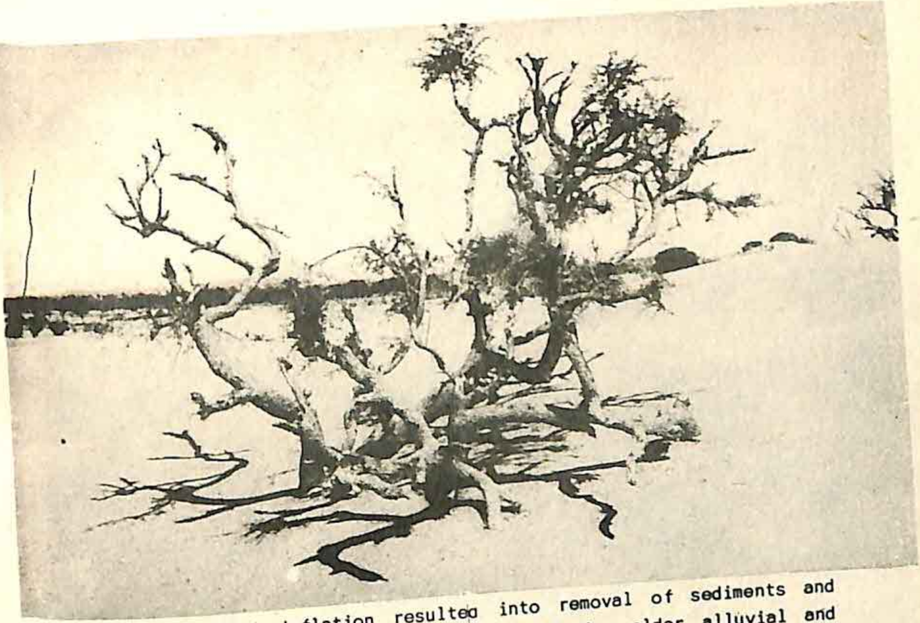

Plate. 5. Wind deflation resulted into removal of sediments and desertification of sandy undulating older alluvial and interdune plains

Plate. 6. Wind deposition hazard resulted into sand piling and desertification of sandy older alluvial plains

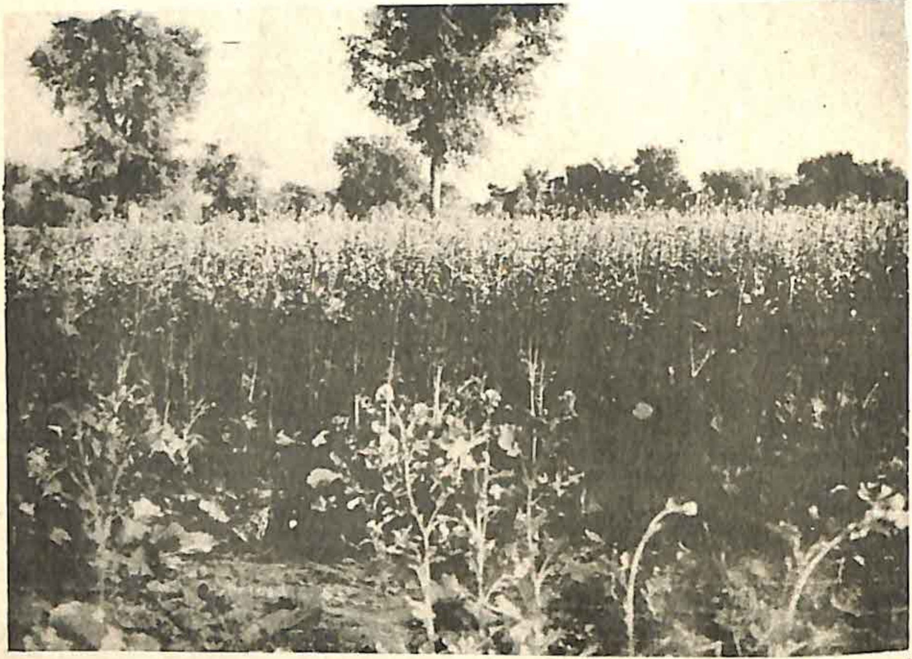

Plate. 7. De-desertification of sandy older alluvial plains due to the exploitation and utilization of groundwater for irrigation

Table 4. Available nutrient status of fresh sediments and original soils

Location	Fresh sediments			Original soils		
	Organic carbon (%)	P_2O_5 (Kg/ha)	K_2O (Kg/ha)	Organic carbon (%)	P_2O_5 (Kg/ha)	K_2O (Kg/ha)
Pipar to Benon on Mitri river	0.05	15	147	0.23	28	342
Bhawi to Bala on Luni river	0.07	66	104	0.15	12	317
Luni to Kankani on Luni river	0.06	13	182	0.17	25	495

Source : Dhir et al; (1982).

It may be seen from the table that the available nutrient status of fresh flood sediments is conspicuously low in all the available nutrients in comparison to original buried soils.

The changes in the morphological features and soil fertility of the younger alluvial plains has also caused the changes in the land use patterns. The cultivated lands where double cropping was practised have been changed into single cropped lands. The wheat, gram and barley crops have been replaced by bajra, moong and moth crops. The growth of bajra is also very stunted and the yield is declined to a great extent.

(iv) POLLUTION HAZARD : The textile industries located at Basni in the southwest of Jodhpur city, in Pali and Balotra are using dyes made from the metals like vanadium and nickel for dyeing and the chemicals such as bleeching powder, castic soda and sulphuric acid for washing. The effluent water produced by the dyes and chemicals was diverted into the jojri and the Bandi rivers. This effluent water remained stagnant and recharged the wells located along the banks of these two rivers. As a result, the water of the open dug wells located in the down stream near Kuri, Sagariya, Bhakrasni, Punaita, Gardara and Muliyawas was polluted by the industrial effluent water. The surface water of the nadis and tankas (cisterns) has also been polluted by the effluent water flowing through the open channels. In the industrial effluent water, the electrical conductivity is 2225 micromhos/cm and the pH varies from 9.7 to 11.7. In the water of the open dug wells located far away from the bank of the above river, the electrical conductivity varies from 783 to 1333 micromhos/cm and pH values range between 8.1 to 8.7. All the wells located close to the stagnant effluent water show considerable faecal pollution MPN index varies from 9 to 64/100 ml, which is much higher than the permissable limit of 10/100 ml.

The polluted water has affected the soils and landuse of the jojri and the Bandi younger alluvial plains. The irrigation by the polluted water due to the presence of the anions like the chloride (298 to 1491 mg/lit), carbonates (11 to 55 mg/lit) and bicarbonates (112 to 495 mg/lit) has created the problem of sodicity in the soils. The hard crust has also developed into the soils which results into the stunted growth of the irrigation crop. (Personal communication N.S. Vangani)

The sodic soils and polluted water used for irrigation have also affected the productivity of the Jojri and the Bandi younger alluvial plains. The double cropped lands have been changed to single cropped lands within a period of two years and at certain locations the lands have become unfit for cultivation. The yields of the irrigated and rainfed crops have also been affected adversely. The wheat yield from 15 to 20 q/ha has come down to 2 to 4 q/ha and that of raya from 5 to 6 q/ha has decreased to 1 to 2 q/ha.

(b) Desertification of the Aeolian Ecosystems

The aeolian ecosystems are more unstable than fluvial ecosystems and their delicate balance has been drastically upset by the increased biotic activities in the few decades. Due to overgrazing, continuous cultivation and deep ploughing of the aeolian ecosystems, the wind deflation and depositional processes have been accelerated and the stabilised sand dunes and sandy plains have been reactivated and degraded to a great extent. As a result, 17.61% and 50.47% areas of the different aeolian ecosystems have been further desertified in the Central Luni basin and the Jodhpur district, respectively. The extent of areas desertified by above desertification processes under different ecosystems is given in Tables 2 and 3.

V WIND HAZARDS

The sand dunes of different types and magnitude in the Jodhpur district are compartively more degraded and reactivated than that of the Central Luni basin. The wind erosion and deposition hazards in the Shergarh-Sai-Suwalia-Sointra sector; Phalodi-Jesalsar-Chadi-Kelensar-Chaku sector and Osian-Samrau-Bhikamkor--Dabri-Khetasar sector of Jodhpur district have further desertified the existing stabilised sand dunes. The fresh sands of 1 to 2m, 2 to 3m and 3 to 4m in the form of sand sheets, transverse ridges and barchan dunes has been deposited which have deteriorated the potentials of these dunes. In this district, 13.31% area under sand dunes has been further desertified. The deflation hollows have been created in the leeward sides of the dunes and at certain places the kankar pan has exposed. In the Central Luni basin, the dunes are only affected in the south western parts in Saila-Padru-Kankhi-Mokalsar sector where the crests have only been reactivated and the thickness of the fresh sand deposits varies 2 to 3 m. But the wind deflation has affected more area and the sediments have been removed from the flanks and the leeward slopes. In the basin only 3.39% area under the sand dunes has been further desertified.

Sandy undulating aggraded older alluvial and interdune plains and also the flat deep sandy aggraded older alluvial plains have also been further desertified due to the increase in the frequency of cultivating the fields and the decrease in the frequency of leaving the agricultural lands fallow for few years. The sediments have been deflated by the wind deflation process from the flat lands lying between the undulations and have been deposited by depositional process on the existing stabilised undulations like sandy hummocks, fence line hummocks and low longitudinal and transverse dunes. (Plate 5). The thickness of the fresh sands on the sandy hummocks is 1 to 2 m, the increase in the height and width of the fence line hummocks is 1 to 2 m and 2 to 3m, respectively and on the dunes of both types the thickness of recent sand deposits varies from .5 to 2.5 m and 2.5 to 4.5m. In the Central Luni basin, the wind deflation and depositional hazards, have damaged 0.72% and 11.70% areas, respectively under sandy undulating aggraded older alluvial and interdune plains and in the Jodhpur district, the above hazards have affected 6.47% and 10.06% areas, respectively under the two ecosystems.

Flat deep sandy undulating aggraded older alluvial plain has only been encountered in Jodhpur district and it occupies 12.98% of the total area of the district. This ecosystem has also been degraded by wind deflation and depositional hazards and the fresh sands have been piled up on the old stabilised sands in the form of sand sheets of 100 to 200 cm thickness near Banar, Kheri Salva, Salva Kalan and Kakalao villages. In Phalodi tehsil, right from Tepu to Jambo, the fresh sands are piled on this ecosystem in the form of sheets and sandy hummocks of 0.5 to 2 m height by aeolian activities. (Plate 6).. The wind deflation and depositional hazards have further desertified 4.14% and 8.75% areas of this ecosystem, respectively.

WIND/WATER HAZARDS

Sandy undulating buried pediments formed against the slopes of the hills near Jalor, Mokalsar, Shergarh, Lavera Kalan, Ratton Ka Bas, Mewasa, Osian and Basni have been desertified by the combined action of wind and water hazards. These accelerated desertification processes have increased the length and width of the existing gullies by 0.5 to 1 m and 2 to 3 m, respectively. The old aeolian sands have been reworked and resulted into sand drifting and deposition on the sand dunes and adjoining cultivated lands in the form of hummocks and dunes of 1.5 to 2.5 m height. The wind and water hazards have desertified 0.24% area in the central Luni basin and 1.7% area in Jodhpur district.

ASSESSMENT OF THE VULNERABILITY OF THE AREAS TO DESERTIFICATION

Digital anlysis of Landsat band 5 computer print out has revealed various degree of vulnerability of the aeolian landforms in the central Luni basin to desertification processes (Shankarnarayan and Singh, 1979).

The extent of the vulnerability of areas to desertification has been computed and presented in Table 5. The areas with dark pixels due to the presence of vegetation and moisture (brightness value 0-65) which occupy 3.36 sq.km. area of the subscene are least vulnerable to desertification. Light to dark grey pixels due to moderately sparse to sparse vegetation (brightness value 66-69) indicate moderately vulnerable areas which constitute 6.07 sq. 'km area of the subscene. Bright, pixels due to the accumulation of fresh sand and absencce of vegetation (Brightness value 70-83) constitute the areas highly vulnerable to desertification and occupy the largest area (11.72 sq. km.) of the subcene.

Table 5. Assessment of the vulnerability of the areas to desertification in the western parts of the central Luni basin

Degree of vulnerability	Gray level	Brightness value	Number of pixels	Extent (Sq.km)	Percentage
Least	1	0-65	745	3.36	15.9
Moderate	2-3	66-69	1346	6.07	28.8
High	4-6	70-83	2599	11.72	55.3
			4690	21.15	100.00

Source : Shankarnarayan and Singh, 1979.

The comparative study of the survey of India topographical sheets of 1960 and Landsat imagery of 1971 and 1973, has revealed the spectacular changes in the saline areas near Sanwarla, Nosra, Samuja, Khutani and between Harji and Manadar. The areas which were nonsaline in 1960 and 1973 have turned saline till 1977 (Shankarnarayan and Singh, 1979) In quantitative terms, it has been ccomputed that in 1960 an area of only 38.12 sq.km. was affected by salinity, but in 1977 the area affected was about 103.60 sq.km; an increase of about 171 percent. The degradation of the soil by this desertification process is indeed alarming from the view point of the decrease in biological productivity of the land.

IMPACT OF DESERTIFICATION ON FERTILITY STATUS OF ECOSYSTEMS

The soil fertility of the different aeolian and fluvial ecosystems due to the accumulation of fresh sands in the form of hummocks, fence line hummocks, sand sheets, brachan and shrub-coppice dunes has been affected.

The effects of human activities on the soil fertility of the aeolian and fluvial ecosystems in Luni basin was studied by Dhir et al. (1976) and the results are presented in Table 6.

Table 6. Available nutrient content of soils under different degrees of wind erosion

Major Land Resources Units (Ecosystems)	No. of samples		Available plant nutrient		
			Organic Carbon %	Phosphorus kg/ha	Potassium kg/ha
Light textured soils of sandy flat aggraded older alluvial plains with moderate incidence of wind erosion	42	Mean	0.16	13.00	138
		SD*		2.43	62
Light textured soils of hummocky aggraded older alluvial plains with severe incidence of erosion	27	Mean	0.14	10.76	134
		SD			68
Dunes with severe wind erosion	18	Mean	0.11	10.72	128
		SD	0.16	4.96	68

*SD Standard Deviation

Source; Dhir et al (1976)

It is apparent from Table 6 that in comparison to moderately eroded sandy alluvial plains, the hummochy aggraded older alluvial plains and sand dunes with loose sand and severe erosion have appreciably lower contents of nutrients elements. These results tend to show the loss ot soil fertility due to wind erosion and if such lands are put to continuous cultivation, as practised currently, the soil fertility will be enormously affected.

3. DE-DESERTIFICATION OF THE ECOSYSTEMS

In the Indian desert, the ground water has been exploited for irrigation under fluvial and aeolian ecosystems viz; flat aggraded older alluvial and interdune plains, flat and sandy undulating buried pediments and sandy undulating aggraded older alluvial and interdune plains. The exploitation and utilization of ground water in Saila-Mokalsar sector, Jalore-Ahor sector, Padru-Dharna-Mithura sector, Kundal-Ramania sector and Muthli-Indrana sector has de-desertified the large acreage of desertified lands by reducing the sand activities and increasing the vegetation density, and agriccultural potentials. In Keru-Beru-Boranda-Jhanwar sector, Pilwa-Judiya-Panchla-Utamtar sector and Bhopalgarh-Bilara-Borunda Ransigaon sector of Jodhpur district and in Sanchore-Kalora-Dhanta and Akoli-Mera-Hiryali sectors of Jalor district, the availability of the ground water for irrigation has minimised the sand activities and the landuse pattern is changed, showing a sign of de-desertification. (Plate 7).

Apart from the Rajasthan desert, the desertic conditions in Koda-Vav-Therad-Suigaon sector of the Gujarat state and Suratgarh-Sirsa-Hansi-Hissar sector of Haryana state due to exploitation and utilization of groundwater are also improved. In these sectors, the sand activities due to its compactness are minimised, micro-climate is slightly changed and vegetation density and landuse potentials of different ecosystems have increased which are showing the sign of de-desertification.

4. SUGGESTIONS TO COMBAT DESERTIFICATION PROCESSES UNDER DIFFERENT ECOSYSTEMS

At present, the increasing biotic activities are largely responsible for accelerating the desertification processes under different ecosystems. In order to combat the further activation of the desertification processes, the following scientific and rational methods for the utilization of different ecosystems are suggested.

a. Since all the environmental problems are related with the inter-action between man, land and water, it is, therefore, suggested that different ecosystems should be properly and scientifically utilised by taking into account their geomorphic properties.

b. In order to avoid the turning of the good agricultural lands into 'bad lands' the controlled grazing and indiscriminate cutting and lopping of trees on different ecosystems and over cultivation should to stopped and grazing lands should be grazed according to their carrying capacity.

c. The complete damming of the ephemeral rivers and the excess irrigation of the agricultural lands by tanks and canals should be avoided so that the impeded drainage conditions and salinity hazards are not developed under different ecosystems.

d. To avoid the salinity hazards, the confluences and the courses of the prior drainage channels which are geomorphologically unstable spots and are impregnated with salts, should not be used for the construction of irrigation network.

e. The sand dunes which are geomorphologically more unstable and highly vulnerable to desertification processes should be completely avoided from grazing and cultivation. These ecosystems should be first developed into silvipastures and after that the grass may be cut and used for stall feeding.

f. To avoid the menace of wind deflation depositional hazards and sand movement the deep ploughing and continuous cultivation by unscientific methods on the flat aggraded older alluvial and interdune plains and sandy undulating aggraded older alluvial plains should be discouraged. These ecosystems form the backbone of the Indian desert in crop production and should be properly utilized by employing suitable dry farming techniques.

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5

ENVIRONMENTAL DEGRADATION DUE TO DESERTIFICATION IN RAJASTHAN DESERT

Amal Kumar Sen

I. INTRODUCTION

1. The Great Indian desert-geographic limitation and origin

The Great Indian desert forms a part of the Thar desert which extends over Pakistan in the west. In India this desert spread over parts of Punjab, Haryana, Rajasthan and Gujarat. The area receiving less than 500 mm of annual rainfall has been taken as the demarcation of the desert (Sen, 1964, 1972). Based upon Koppen's (1930) index, the annual rainfall being less than T+14 the area is classed as arid region. Gorczynski's (Banerji 1952) aridity factor and Gaussen's (1959) xerothermic index work out to 30 and 300 respectively which are also indices of true arid or desert climate. This also coincides mostly with the boundary drawn on Thorntwaite's (1943) evapotranspiration and precipitation ratio.

This climatic analysis is further supplemented by the following physiographic observations:

(a) The rivers are misfit and soon die out due to alluvial suffocation. The drainage except the Luni and the Mendah which has its origin in the region of very high rainfall and thus capable of forming its own valley, is mostly internal and there are no permanent flowing rivers.

(b) There is no network of integrated drainage system and no controlling level to which the landscape is lowered. Instead, the rivers deposit their load and sink into alluvium covered ground.

(c) The Debris resulting out of gullying and dissection of mountains are accumulated in the intermont basins.

(d) Alluvial sand becomes laterally confluent and continuously sloping 'bajadas' are formed along mountain fronts.

All these geomorphic factors are characteristic of an arid climate and are found exclusively in areas receiving less than 500 mm of annual rainfall. Therefore, the 500 mm isohyet has been taken as the scientific basis for cartographic expression to delimit the desert. The great Indian desert of N.W. India, as such, extends approximately between 31°N and 21°N and between 69°E and 76°E, comprising an area of about 295,000 sq.km. After considering the geographic and climatic aspects in an earlier communication Sen (1971) concluded that this desert is a true desert having its origin due to the same climatic oscillations during the pleistocene which resulted in the formation of middle and low latitude deserts. The desiccation of the Saraswati or the Ghaggar had nothing to do with the origin of this desert. A subsidence in the Ganges delta aided by a latter uplift during subrecent times in the Aravalli-Delhi axis led to the gradual rise of the Eocene sea floor of the Indian desert. This resulted in the shifting of the Yamuna,' which was hitherto a tributary of the Saraswati of the Indus system (the combined stream of the Sarsawati and the Yamuna was known as Ghaggar) to the Ganges system (Oldham, 1886 , 1893; Kaushic, 1968). The increased aridity, due to the rise of the Himalayas and lowering of the Aravallis probably caused the shifting and desiccation of the rivers like the Saraswati that made the desert gradually uninhabitable and made the people of the Saraswati and the Ghaggar valley as nomadic. Uneconomic exploitation of resources and deforestation contributed little to this deterioration. This is purely a climatic and physiographic phenomenon as in other tropical and subtropical deserts of the globe.

The desertification process, in all its probable ramifications and their interplays, has been defined as package of processes which brings about certain basic changes in a particular ecosystem and converts it relatively non-desertic to a desertic terrain. This involves an interplay of climatic, edaphic and biotic factors which may work through time starting with a climatic accident and ultimately resulting in the formation of desert or lead to accentuation of the arid conditions within an already desertic terrain or cause a creep of the desertic conditions within a desertic tract towards its adjoining areas.

3. DESERTIFICATION - DEFINITION AND PROCESSES

Desertification, from the grammarian point of view means conversion of a fertile or non-desertic land towards a dry infertile or desertic land or better still a 'desertion' land. The term 'Desertification' is in circulation and may indeed win the laxicographer's approval in the near future.

Desertification to an ecologist or environmental scientist is a systematic phenomenon involving climate, soils, flora, fauna and man. It may be regarded as a form of deterioration of the ecosystem due to change in the pressure of human adaptation or use system. Desertification arises from the fragility of the dryland ecosystems which under excessive pressure of human use lose productivity and ability to recover. Stability and resiliance are major factors in the viability of all the system - social and cultural as well as physical and biological.

Desertification, therefore, can be defined as a package of processes which brings about certain basic changes in a particular ecosystem and converts it from a relatively non-desertic to a desertic terrain. This involves an interplay of climatic, edaphic and biotic factors which may (a) work through time starting with a climatic accident and ultimately resulting in the formation of a desert, or (b) lead to accentuation of the arid conditions within an already desertic terrain or (c) cause a creep of the desertic conditions within a desertic tract towards its adjoining areas.

Although desertification can develop from natural cause alone and in any climatic zone or ecosystem, the U.N. Conference at Nairobi in 1977 mainly focussed attention with desertification that derives from interaction of human use system with natural ecosystem in the arid, semi-arid, sub-humid and humid zones. For these reasons desertification must be diagnosed and monitored through the whole range of physical, biological and social processes relevant to ecosystem and human adaptation of drylands. Because when the balance of an ecosystem breakdown due to effect of desertification, it may be difficult to constitute a viable human use system as to restore primary productivity. As a result while the productivity of the natural resources is partially lost through desertification, this productivity may be totally lost to human community. Hence if people are mainly responsible for desertification it is equally most efficiently combated by diagnosing and arresting the social and economic processes that lead to it.

Thus desertification is mainly a man made problem which leads to the environmental degradation of fertile lands. The basic cause of desertification is the inter-relationships between the natural or physico-environmental system and the various human adaptations. This is because the environment (when difined as the sum total of the conditions that control human activities) are under stress of human needs or adaptation (when adaptation is defined as the various means the human being adapt to survive themselves). Thus it is the human activities that primarily initiate desertification processes. With this, the quality of resource management should be added or considered. This skill is also important. Over exploitation of resources cannot be ignored. The two combine to add to the intensity of environmental degradation or desertification hazards. Some of the main human and biotic interactions that are causing desertification hazards are :

(i) Uneconomic land use - cultivation on the sand dunes, marginal lands affecting adjacent fertile lands and a menace to soil erosion.

(ii) The intensive and uneconomic or over exploitation of water resources - leading to rise of water table, seepage problems and problems of increased salinity.

(iii) Uncontrolled grazing and indiscriminate cutting of trees or over exploitation of grazing lands and forest resources leading to drought, soil erosion, deterioration of soil fertility and stunted growth of trees.

These activities cannot be totally suspended but definitely subject to control by proper management of resources. Accordingly Desertification exists in all the areas and will continue to be a problem.

11. Possible expansion of the Indian desert

After considering the geographic and climatic aspects in an earlier communication, Sen (1971) concluded that the Rajasthan desert, which is a part of the Great Indian or the Thar desert is a true desert having its origin due to the same climatic oscillations during the pleistocene, long after the Himalayas have come into existence, which resulted in the formation of middle and low latitude deserts. The possible expansion of the Rajasthan desert has been studied through a series of maps prepared on the basis of geomorphic and other physiographic features (Sen, 1972). The problem has also been examined through quantitative comparisons of economic parameters like land use, water availability and crop yield performances (Sen 1972, Mann, Malhotra and Kalla 1974) between desert areas and bordering regions. All available evidences suggest that the Rajasthan desert, has not, and is not, advancing towards the east but that fresh sand deposition is still going on and towards the west (within the desert), the desertis conditions have further deteriorated in the recent past (Sen and Mann, 1977). The inherent vulnerability of the land and intense biotic pressure have combined to set in a process of deterioration within the desert.

111. Environmental degradation of the Indian desert.

There is, however, an unanimity with regard to the deterioration of desert by human and other biotic interference which need careful considerations. Desert conditions must have set in India, particularly in Rajasthan well after man appeared and actually in geological sub-recent times long after the last phase of the glaciation. The Himalayas was already in existence when the desertic conditions were set in and were continuing to rise during this period. The monsoon conditions were established in India after the Miocene when the Himalayas became a prominent feature in the north. Prior to that the present desertic area of N.W. India including western Rajasthan were drained by mighty Himalayan - glacial fed rivers like the Saraswati, the Sutlej and the Indus. The Saraswati was a great river in the vedic period flowing through the present day dry bed of the Ghaggar into the Rann of Kutch. At one time there must have been numerous streams in western Rajasthan (Krishnan 1952) which flowed either to the Saraswati or into Rann of Kutch. The latter was at that time, a gulf with three large rivers-the Luni, the Saraswati and the Indus, flowing into it. The river systems which rise on the Aravallis and in the highlands of south-eastern Rajasthan must have had a long history stretching back to some millions of years. But most of the Himalayan rivers-the Saraswati, the Indus, the Yamuna, began their history from about the middle Miocene when the mountains were being uplifted and were gradually attaining their present configuration and height (Krishnan 1952). Sir Aurel Stein (1942) has traced the existence of prehistoric settlements upto near Fort Abbas on the Hakra. Taking into considerations the area explored the valleys of the Saraswati and the Drishadvati (Ghosh 1952) must be regarded very rich indeed in archaeological remains. They comprise relics of several millennia of Indian history right from the Indus valley civilization (Mohanjodaro-Harappa) period (3000 B.C.) to comparatively recent

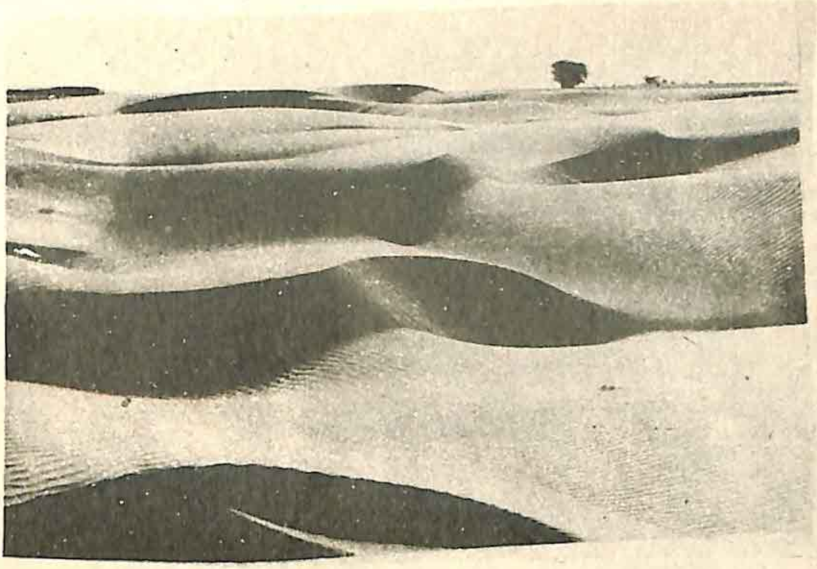

Photo 1. Sand movement - Due to strong wind action - A Natural process of desertification (Aerodynamics).

Photo 2. Enlargement of Rocks - An indicator of desertification due to prolonged weathering and wind action.

Photo 3. Highly demanded hill (Arvallis) due to prolonged wind action - A natural process of desertification

Photo 4. Overexploitation of forest and tree resources An indicator of desertification (Anthropogenic).

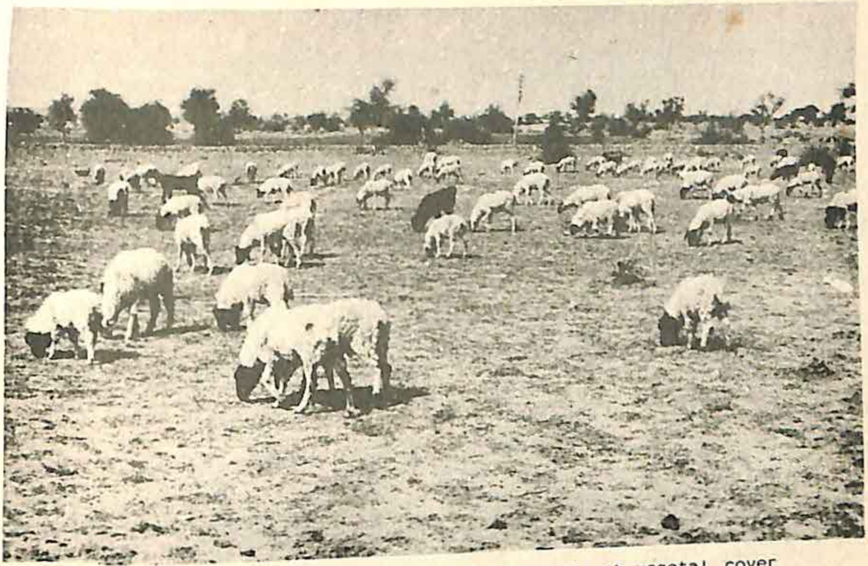

Photo 5. Overgrazing leads to the removal of vegetal cover and top soils - An indicator of desertification (Anthropogenic).

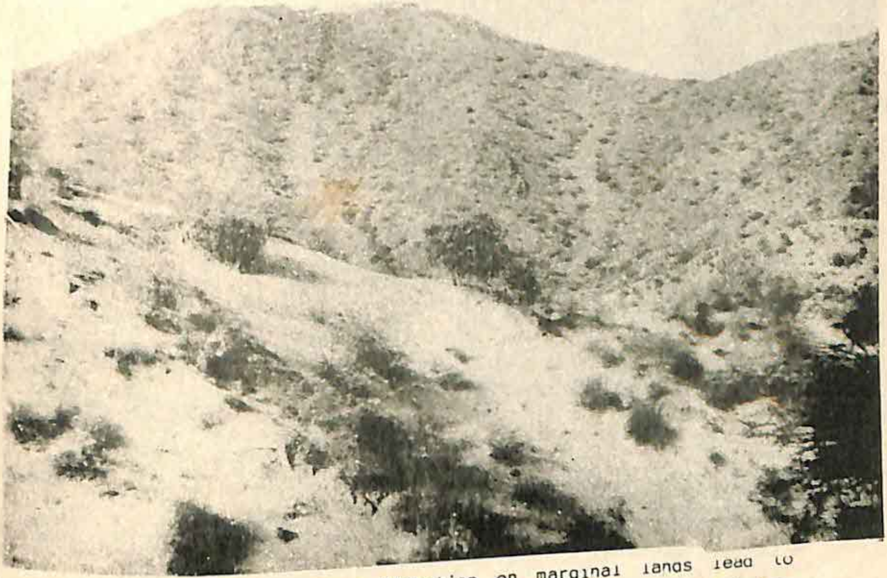

Photo 6. Uneconomic cultivation on marginal lands lead to vertical movement of wind which may cover the hills and infrastructure - An indicator of desertification (Anthropogeni).

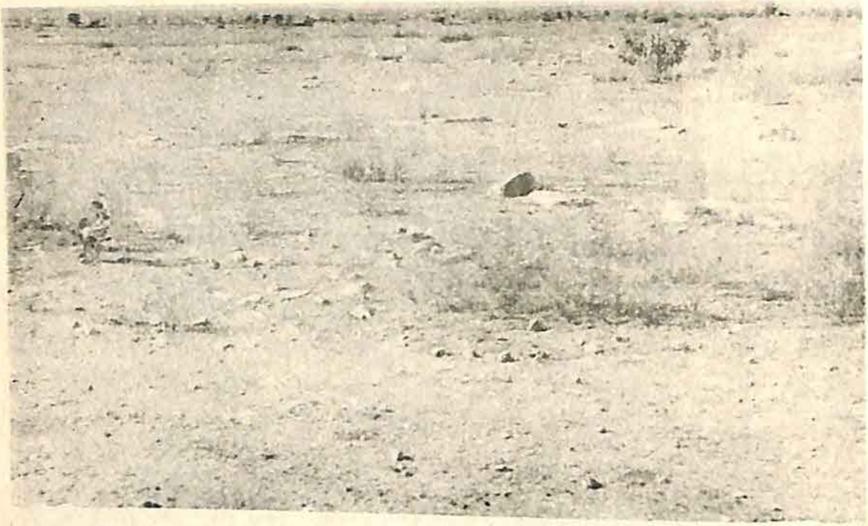

Photo 7. Overgrazing and indiscriminate cutting of trees expose the base rocks and remove Top soils - An indicator of desertification (Anthropogenic).

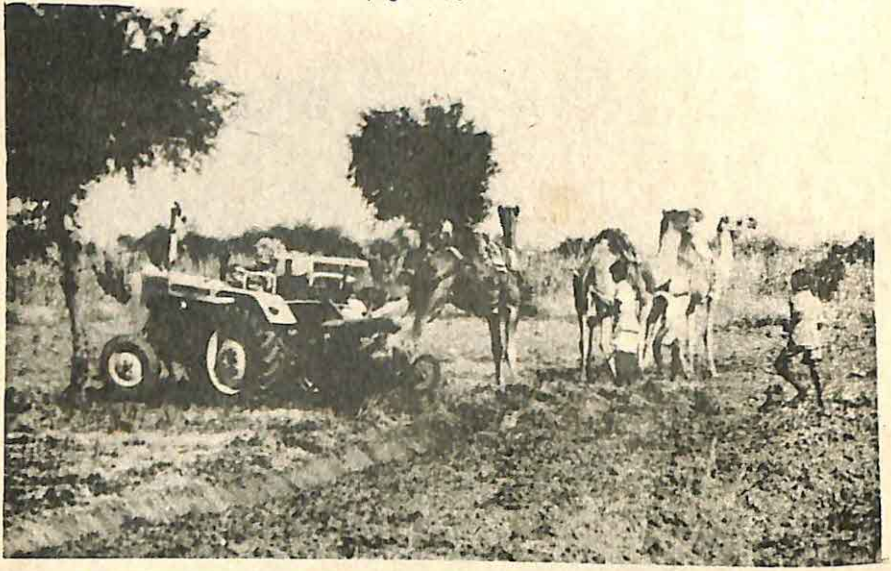

Photo 8. Mechanisation in cultivation in marginal lands lead to sand movement - Amenace of soil erosion and desertification (Anthropogenic).

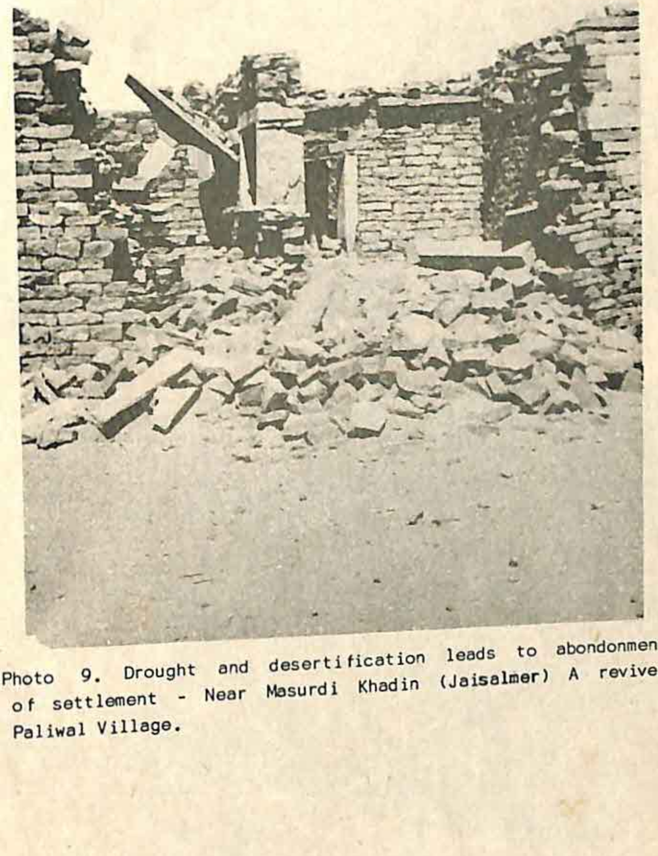

Photo 9. Drought and desertification leads to abondonment of settlement - Near Masurdi Khadin (Jaisalmer) A revived Paliwal Village.

Photo 10. Shelter belt at Sura.garh - A meanse of combating desertification.

Photo 11. Road side plentation - A meanse of combating desertification.

historical times. In the Saraswati valley, as explored, the colossal mound of Kalibanga near Pilibanga and Suratgarh, exhibit the presence of great urban civilization in the heart of the Indian desert of today. The fist condition led to the deterioration of the Indian desert area was due to the increase of aridity caused by the rise of the Himalayas and lowering of the Aravallis (due to isostatic adjustment). This led to the shifting and desiccation of rivers like the Saraswati. A subsidence in the Ganges delta aided by a later uplift during subrecent times in the Aravalli-Delhi axis led to the gradual rise of the Eocene sea floor of the Indian desert. This uplift of the putwar plateau during the late Pleistocene had probably a great effect on the drainage system of the Himalayas, causing shifting and capturing of some streams like the Yamuna which was hitherto a tributary of the Saraswati towards the east. This increased aridity and the resulted shifting and desiccation of the rivers made the desert gradually uninhabitable and made the people nomadic (Sen and Mann 1977). The part dry river beds became the part of the source of sands which aggraded during the arid phases and later played on the pile up in the form of dune with the increased aridity aeolian phases accentuated. Hence, the origin of the desert is essentially a climatic and physiographic phenomenon and certainly not man made one.

But it is the human activities; uneconomic exploitation of resources and land use practices and other biotic interference that have made the desert more and more uninhabitable.

Some of the main human and biotic interference that are causing the deterioration of the Rajasthan desert are given below (observed during the year under report):

1. Uneconomic land use :-Cultivation on the sand dunes and marginal lands affecting adjacent fertile lands and is a menace to soil erosion. This has caused reactivisation of sand cunes

in canal command area at Nachna.

(2) The intensive and uneconomic use of canal irrigation - extensive use of water resources leading to the rise of water tables, seepage problems and increased salinity near Bhikampur, Chinnu and Nachna area of Jaisalmer district.

(3) Uncontrolled grazing and indiscriminate cutting of trees leading to soil erosion and increased desertification hazards at Kuri area near desert National Park in Jaisalmer district.

IV. Environmental degradation due to desertification-Specific field study in area of ecocrisis

After considering the geographic and climatic aspects and through quantitative comparison of physical and socio-economic parameters, the problems on the possible expansion of the Indian desert towards the east of the Aravallis have been examined by the scientists of CAZRI since 1960. All available evidences suggest that the Rajasthan desert, has not, and is not advancing towards the east, but fresh sand deposition is still going on towards the west, within the desert, and the desertic conditions have further deteriorated within the desert in the recent past are quite evident. The inherent vulnerability of the land and intense biotic pressure (along with human land use system or adaptation) have combined to set in a process of desertification hazards leading to environmental degradation or deterioration of the Indian desert. Some of these biotic interferences causing in western Rajasthan are:

1. DESERTIFICATION DUE TO OVER EXPLOITATION OF RESOURCES AND UNECONOMIC LAND USE PRACTICES:

Uneconomic exploitation of resources and land use practices is one of the main process of desertification that have made the desert more uninhabitable.

Due to intensive pressure on land and absence of subsidiary occupations compel the people (incidentally Indian arid zone is the highly densely populated desert of the world) to cultivate the dunes and marginal lands. This causes the loosening of sand particles which become susceptible to be carried by the winds. These wind bourne sands fall on the adjacent fertile lands and ultimately deteriorate them. Hence the system is a menace of soil erosion and desertification hazard. Cultivation of the sand dunes and marginal lands in Nagaur, Bikaner, Churu and Pali districts has caused the shifting of the sands in Kuchaman, Ghataru, Didwana, Taragarh areas and formation of new sandy humocks or low dunes along Didwana - Molasar-Kuchaman and Sujangarh-Sikar tracts causing deterioration of the fertile lands. The sandy wastes along Tilonia in Ajmer district appears to be due to the fresh deposition of aeolian sand due to the cultivation of the marginal lands along the Aravallis (western scarp) in Nagaur district. Cultivation on dunes in Sikar, Palsana, Lachmangarh, Fatehpur, Ratangarh is ccommon and accordingly the fertile lands of Churu, Sikar and Jhunjhunu districts are seriously affected.

Over-exploitation (cultivation) on the marginal lands and deserted sandy river beds towards the west and north west of Ajmer and Pushkar have shown slow advance of sandy materials through Luni gaps engulfing more fertile lands towards the east of Aravallis causing disorganisation of the drainage system (as in the cases of the Mendha, Saraswati-Sagarmati interfluve between Govindgarh and Pisangan) and deteriorating adjacent fertile lands (like the environ of the Savitri hillocks at Pushkar). (map 1) Due to some reason huge mobile or active sand dunes are being formed in Pokaran-Banyana-Phalsund tract in Jaisalmer district. In Barmer district, particularly towards Chotan - Bakhasar - Gandharv areas constant cultivation on sand dunes and marginal lands are leading to the fresh deposition of sand on fertile lands. The reactivisation of sand dunes, due to biotic interference viz., uneconomic land use, overgrazing, urban fringe activities are also affecting highways, railways, settlements as evident in Ganganagar district (Nohar), Bikaner, Churu, Jaisalmer, etc.

The livestock population and that of pressure on the grazing land in Rajasthan is considerably high (Tables 1 & 2). The result has been overgrazing and deterioration of the surface vegetation conditions, largely responsible for increased desertification hazard. In western Rajasthan in view of their low carrying capacity, the increased pressure of livestock on the grazing lands results in over-exploitation of resources leading to depletion of consequences on settlements, commercial and other infrastructure like Nachna, Churu etc. This is also a menace to soil erosion leading to the removal of surface vegetation and soil. The absence of organised livestock farming is strongly felt. This also cause the shifting of sands which often cover the existing settlements and even the hills. A hill towards the north east of Barmer town which has been reported 60 years back to be free of sand is now almost buried. Sand dune fixation works undertaken about 15 years back has partially stopped this serious catastrophe. Uncontrolled grazing (over-grazing) is often added with indiscriminate cutting of trees and lopping to make the desertifidation hazard more intensive.

Over-exploitation of ground and surface water resources for intensive and uneconomicc use for irrigation leads to the rise of water table, seepage problems, waterlogging and increased salinity. Over exploitation of ground water:irrigation in Mathania-Rampura-Indrokha area resulted the irrigated farming on the sandy wastes, sand dunes and marginal lands. This resulted the shifting of sands causing the formation of sand dunes, piling up of sands towards the south west near Balesar-Shergarh area in expanse of double cropped lands of Indrokha-Mathania area. This burried recently the Jodhpur-Shergarh road near Balesar due to the piling up of fresh sands. As a result the road has to be deserted from its old tract.

Uneconomic and intensive uses of canal water in the Ganganagar, Bikaner and Jaisalmer districts have developed some alarming problems. In Gang canal and Rajasthan Canal command areas in Ganganagar district due to sandy terrain and seepage losses from main canal, distribution and field channels, the ground water level is rising at an alarming rate of 0.43 to 0.83 m per year. In the Ghaggar flood area around Suratgarh, Borpal, Manekthar areas water table has risen by 6-5 metres within past 20 years. Due to this rise of water level 6920 mcm water is being added to the aquifer annually leading to the development of soil salinity (Kallar) in many places. The increase of water table and Ghaggar flood has caused water logging problems in interdune areas (23 interdune areas near Suratgarh has already been submerged and become permanently water logged) has threatened the existence of prehistoric excavation sites at Kalibanga (3000-2700 B.C.), Rangmahal (2000 B.C.), Hanumangarh, Anupgarh etc. The rise of water table has also caused seepage problems in Ganganagar. Also in Nachna area in Jaisalmer district, where the canal system has only recently been introduced, the seepage problem has been noticed. If in the canal irrigated area, the present rate in ground water level is allowed to continue then 20, 40 and 60 perccent of the canal command area is likely to develop drainage and salinity problems within 30, 30 to 50 and 50 to 100 years respectively. Canal irrigation on the sand dunes and marginal lands in Nohar and Bhadra area of Ganganagar and Lunkaransar area of Bikaner districts are causing the fresh deposition of sands, formation of new sands dunes and other environmental degradation

Table 1. Pasture Grounds in Western Rajasthan

District	Total Area	Pasture land in ha & %			Total & Per cent pasture lands to total area
		Permanent pasture/ oran	Waste lands	Marginal land	
I A Jodhpur	2217800	133500 (6.02)	682790 (30.79)	271560 (12.55)	1087940 (49.55)
Bikaner	2885072	26597 (0.92)	14117020 (49.12)	294380 (10.12)	1737997 (60.2)
Barmer	2817294	214466 (7.61)	501974 (17.82)	19285 (0.7)	735725 (26.1)
Total arid Monocropping	13740980	569232 (4.14)	6293608 (45.90)	690479 (5.02)	7553319 (55.1)
I B Ganganagar	2041446	25910 (1.27)	301451 (14.77)	38792 (3.0)	486353 (19.0)
Total arid	15782426	595142 (3.77)	9595059 (41.78)	6729471 (4.62)	7919672 (50.2)
Sikar	774925	48220 (6.22)	71041 (9.17)	1889 (0.24)	121130 (15.6)
Jhunjhunu	592730	44589 (7.53)	24924 (4.20)	1826 (0.30)	71339 (12.3)
Total Transitional Monocropping	3135666	173189 (5.53)	180565 (5.76)	143602 (4.60)	497356 (15.8)
2 B Jalore	1056357	511709	96709	656	148504
Pali	1229762	92463 (7.52)	178144 (14.49)	19962 (1.62)	290569 (23.6)
Total Transition Kharif and Rabi cropping	2286119	143602 (6.28)	274853 (12.02)	20618 (0.90)	439073 (19.2)
Total Transitional Arid & Semi arid	5421785	136791 (5.84)	455418 (8.40)	164220 (3.03)	236429 (17.2)
Total W. Rajasthan	12204211	911233 (4.30)	7050577 (33.25)	893691 (4.21)	8856101 (41.8)

Table 2. Livestock population : Grazing area/Livestock in ha and pressure of livestock population on grazing land

Districts	Total grazing ground in ha	1972 (Total	Grazing land/ livestock	1977	Grazing land/ livestock
Bikaner	1737927*	898760	1.93	1534983 (+70.78)	1.13
Barmer	735725	1974350	0.37	2534983 (+28.26)	0.29
Churu	208504	1426375	0.14	1574522 (+10.38)	0.13
Jodhpur	1087940	1893200	0.57	2442424 (+29.018)	0.44
Jaisalmer	3783152	616434	6.14	1300419 (110.95)	2.91
Ganganagar	386353	1533671	0.25	1645431 (+7.287)	0.23
Sikar	121130	1530178	0.98	1361092 (-1.05)	0.08
Jhunjhunu	71339	978508	00.7	968588 (-1.01)	0.07
Nagaur	184283	2304290	0.08	237141 (+2.93)	0.07
Jalore	148504	1234772	0.12	1322045 (+7.06)	0.11
Pali	290569	1893650	6.15	1913093 (+4.72)	0.14
Total	8856101	14584108	0.61	19036651	0.46

in Churu (Sardarsahar-Ratangarh-Taragarh area); Sikar and Jhunjhunu districts. Actually the condition of Churu has become more vulnerable and alarming. The district has recently shown considerable increase of desert sand, sand drifts and the existing stabilized dunes are increased vertically and new sand dunes are developing around Churu Taragarh etc.

2 ENVIRONMENTAL DEGRADATION DUE TO DESERTIFICATION - SPECIFIC EXAMPLES IN AREAS OF ECOCRISIS

Some specific examples as concluded from the integrated basic resources and land use surveys in different areas of western Rajasthan are described next.

3 CULTIVATION ON SAND DUNES AND MOVEMENT AND ENCROACHMENT OF WIND BLOWN SANDS (SEN 1977) -

In actual practice, sand dunes are not universally sandy wastes. These are rather often cultivated during rainy season. The active sand dunes are often wastelands but the lower and middle flanks of these dunes are cultivated in years of very good rainfall, particularly in rainfall zone of over 200 mm. Long fallows of five years duration in 200 mm - 300 mm zone and 2-3 years duration in rainfall zone of over 300 mm are evident. Upper flank and crest of the dunes serve as grazing ground of the livestock. Hene in sand dunes, three land use units viz. cultivated or cultivable (including short and long fallows), sandy waste and grazing grounds can be mapped. But these details can be mapped only on 1:50,000 scale and above through aerial photo interpretation, particularly "edge gradient" study. This, however, is also not possible by traditional ground survey.

The findings of aerial photo interpretation and consequent ground survey regarding land use and their consequences on deteriorating the desert is presented in Table 3.

Uneconomic land use, overgrazing and indiscriminate cutting of trees have resulted the increase of desert sand and formation of huge mobile or active sand dunes in many areas, e.g. Phalsund-Pokaran Banyana tract in Jaisalmer district. Recent investigations have shown a slow advance of sandy materials

Table 3. Land use of the sand dunes

Dune Particular	Land use	Remarks
Stabilized dunes and sandy plain : Lower & Middle flanks	Cultivated	Soil erosion is menace to adjacent land.
Stabilized dunes : Lower and middle flank.	Short fallow	Cultivation should not be practiced which may lead to the enroachment of sand in adjacent fertile lands.
Stabilized dunes : Middle and upper flank.	Long fallow	
Unstabilized dunes		To be fenaced.
Marginal lands : crests	Sandy waste	Recommended for range land
Unstabilized sand dunes	Sandy waste	To be fenced. No biotic activities.
Crests and upper flanks of stabilized dunes	Sandy waste	Controlled grazing.

through Luni and Sambhar gaps engulfing more fertile lands towards the east of the Aravallis causing disorganization of the drainage system and deteriorating adjacent fertile lands. It is possible that the problem is much more extensive. Accordingly there is a need for further investigation. The study further reveals (Sen and Mann 1977) - i) fresh sand movement is an active phenomena in the arid zone, ii) the general trend of the increase is towards the North-West, iii) the reacctivization of sand dunes, due to biotic interference, viz. uneconomic land use, overgrazing, urban fringe activities - affecting highways, railways, etc., and v) fresh movement of sand affecting settlements and communications in canal command area.

4 UNECONOMIC LANDUSE PRACTICES AND OVER-EXPLOITATION OF WATER RESOURCES IN RAJASTHAN CANAL PROJECT AREA (SEN 1981)-

Investigation on landuse carried out in between

74°45 to 75°0'E and 29°30'N to 29°15'N just to the south of the older Ghaggar river bed (in Hissar districts of Harayana) and southern Ghaggar canal revealed some interesting features.

The southern part of the region was waterlogged flanked by sandy hummocks and sand dunes as mapped by Survey of India during 1912-14. The reclamation of the water logged areas and the marginal lands by irrigation later converted them into cultivated lands with high intensity of 80 to 100 per cent. But the cultivation of the marginal lands and sand dunes have caused the shifting and deposition of sands further south near Jasane, Ramsara, Ratanpura, Rajkawa etc., which were dune free during 1912-14, and have now become the sites of high dune intensity as revealed from the aerial photographs and SOI top-sheets surveyed during 1960-61.

Recent survey (September 1978) has shown further increase of sands throughout the area which is due to the indiscriminate cutting of the shrubs and trees. This has led to the deterioration of good agricultural lands and has increased the desertification intensity. The inundated areas which were waterlogged as early as in 1912 have become saline and this particular problem is gradually increasing towards the south in recent years.

The study thus sharply bring into focus the biotic interferences of the marginal lands which should be scientifically managed alongwith judicious exploitation of water resources.

The seepage problems along the canal irrigated areas have caused water logged areas in Suratgarh, Tibi, Hanumangarh, Anupgarh areas. This has increased the salinity hazards.

The overgrazing and cultivation of the sand dunes and the marginal lands in Bhadra, Nohar and Suratgarh tehsils has led to the shifting of sands in the adjacent Churu district. The district has recently shown an considerable increase of desert sand, sand drifts and the existing stabilized dunes are increased vertically and new sand dunes are developing round Churu, Taranagar Tehsils.

The intesive and uneconomic irrigation has caused waterlogging problems and an area of about 20 sq.km. has been submerged near Suratgarh area.

The water table has been considerably increased round Suratgarh, Baropal and Rangmahal areas. This has threatened the prehistoric excavation situated Rangmahal, Hanumangarh and drybeds of Saraswati or Ghaggar, etc.

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CLIMATIC CHANGES IN RELATION TO DESERTIFICATION IN THE INDIAN ARID ZONE

Y.S.Rama Krishna

I. ABSTRACT

Rainfall variability in the Indian arid zone does not indicate any secular trend. The region in general experienced a deficit rainfall spell of large magnitude and duration during the decade 1961-1970 which was comparable only to a deficit spell of such magnitude that occurred at the end of last century during 1895-1905. The climatic spectrum of the Indian arid zone was found to extend from extermely arid to semi-arid conditions but annual moisture index values generally remained below normal in large number of years and the fluctuations from arid to extremely arid conditions in these regions are offset by a large positive departure to semi-arid conditions only occassionally. The shifts in the aridity index line of 80.0 does not show any definite and continuous increase of desertification conditions in the Indian arid zone and whatever shifts have occurred were only temporary causing mild spurts of desertification. Droughts of severe nature were found to occurs once in 3 to 4 years in Jaisalmer, Barmer, and Jalore region and the probabilities of extreme arid conditions were observed to be higher in the western part of Rajasthan. Occurrence of deficit rainfall and drought conditions have a multiplier effect increasing dust storm activity during the subsequent year and leading to increased wind erosion and desertific conditions in the Indian arid zone.

II. INTRODUCTION

About 62 per cent of the total arid zone in India covering an area of 1,96,150 km² lies in western Rjasthan thus forming the principal arid zone in the country. This region is characterized by low and erratic rainfall distribution , extreme variations of diurnal and annual temperature high evaporation and strong wind regime during the summer and early monsoon season. Considerable variations occur in the moisture regime of the Indian arid zone due to high year to year variability of annual rainfall. Jodhpur for example recorded the highest rainfall of 1178 mm in 1917 followed by the lowest of 38 mm in 1918 against an average rainfall of 373 mm. The coefficient of variability of annual rainfall varies from 40 to more than 70 per cent across western Rajasthan indicating thereby that the year to year variability in annual rainfall assumes very high proportions in the extreme arid regions. These large fluctuations in year to year rainfall and the variability in the distribution of the annual rainfall itself causes considerable year to year variability in the climatic patterns of western Rajasthan and exposes many of the regions to the problem of desertification. The escalating human and livestock population of the Indian arid zone result in the over exploitation of the vegetation and increased pressure of land during the years of drought which are very frequent leading to deteriorating desert environment and enhancing the process of desertification.

Recent studies on desertification carried out by CAZRI show that 4.35 per cent of western Rajasthan has already been effected by the process of desertification and another 76 per cent area is moderately vulnerable to desertification (CAZRI, 1981). The present paper brings about the climatic changes relating to desertification that have occurred during the past eight decades (1901-1980) in the Indian arid zone.

III. RAINFALL VARIABILITY

Conflicting views have been presented on the trends in annual rainfall of the arid zone of north-west India by various workers. Banerji (1952) indicated a slight decrease of rainfall during the 50 years ending in 1950 in Rajasthan excepting for the stations situated in the Aravalis. The same, however, had been disproved by Pramanik, Hariharan and Ghose (1952), Pramanik and Jagannadhan (1954) and Rao (1958).

As such to obtain a clearer understanding of the rainfall variability over the Indian arid zone based on the recent data (1891-1984), the trends in annual rainfall for different stations in western Rajasthan were studied at CAZRI using five yearly moving averages technique in respect of three stations in the Indian arid zone (Fig 1). The portion of graph in these figures in respect of years when below normal rainfall conditions existed have been shaded. The study of the five yearly moving average of rainfall in the Indian arid zone indicates that a deficit rainfall spell of large magnitude and duration occurred in many regions of the arid zone during the period 1962 to 1971. At Jodhpur and Pali it was seen that the dereasing trend started from 1956 itself. The below normal spells that have occurred previous to 1960 were mostly of small magnitude and only the very large below normal rainfall spell that occurred during 1895 to 1905 alone is comparable to that experienced in the Indian arid zone during the period 1962-71. The rainfall, however, indicated an increasing trend during the seventies as a result of above normal rainfall over most of the arid zone during 1970, 1973, 1975, 1976 and 1979. Thus at most of the stations in the Indian arid zone, the annual rainfall indicated a decreasing trend during the period 1956 to 1969 and an increasing pattern thereafter (Fig 2). The only exception to this pattern has been in the northwest region at Churu which

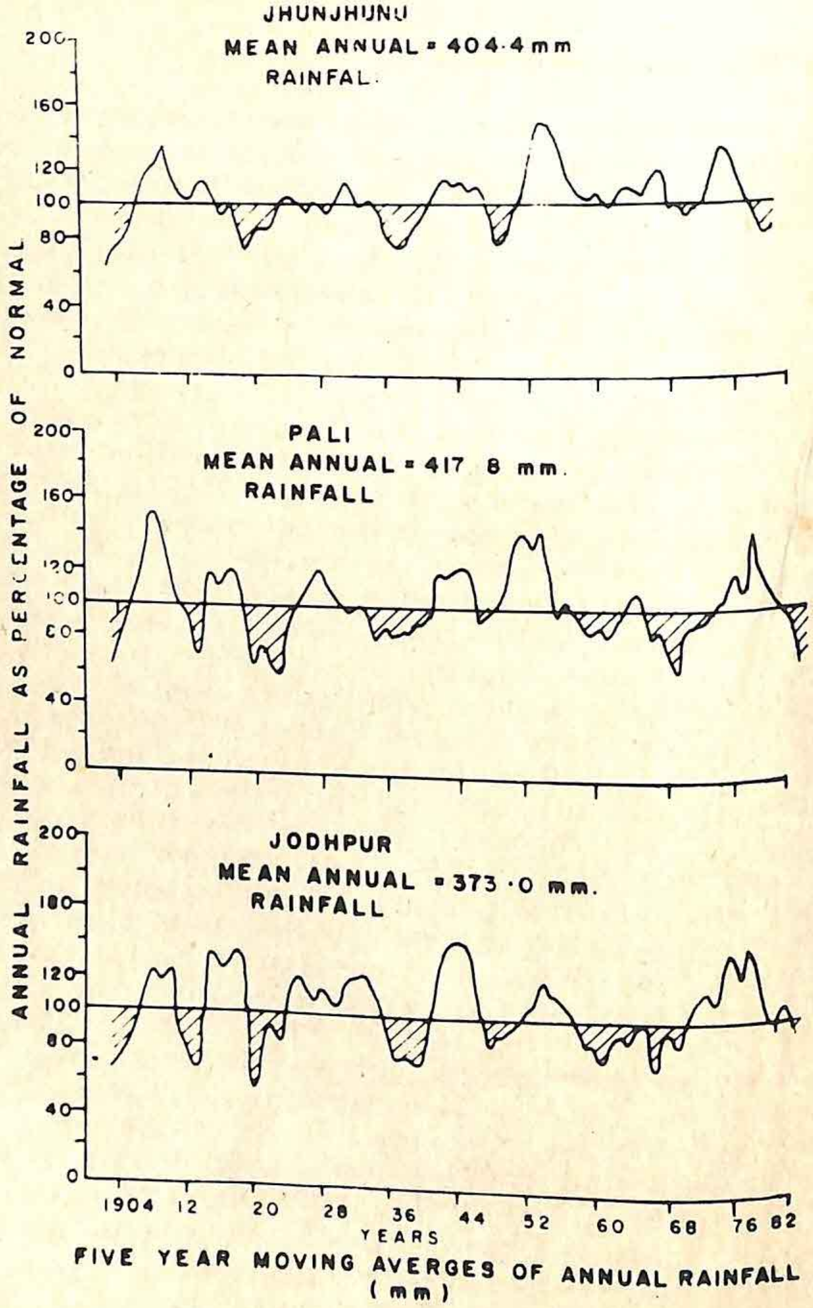


Fig 1. Five year moving averages of rainfall in Western Rajasthan

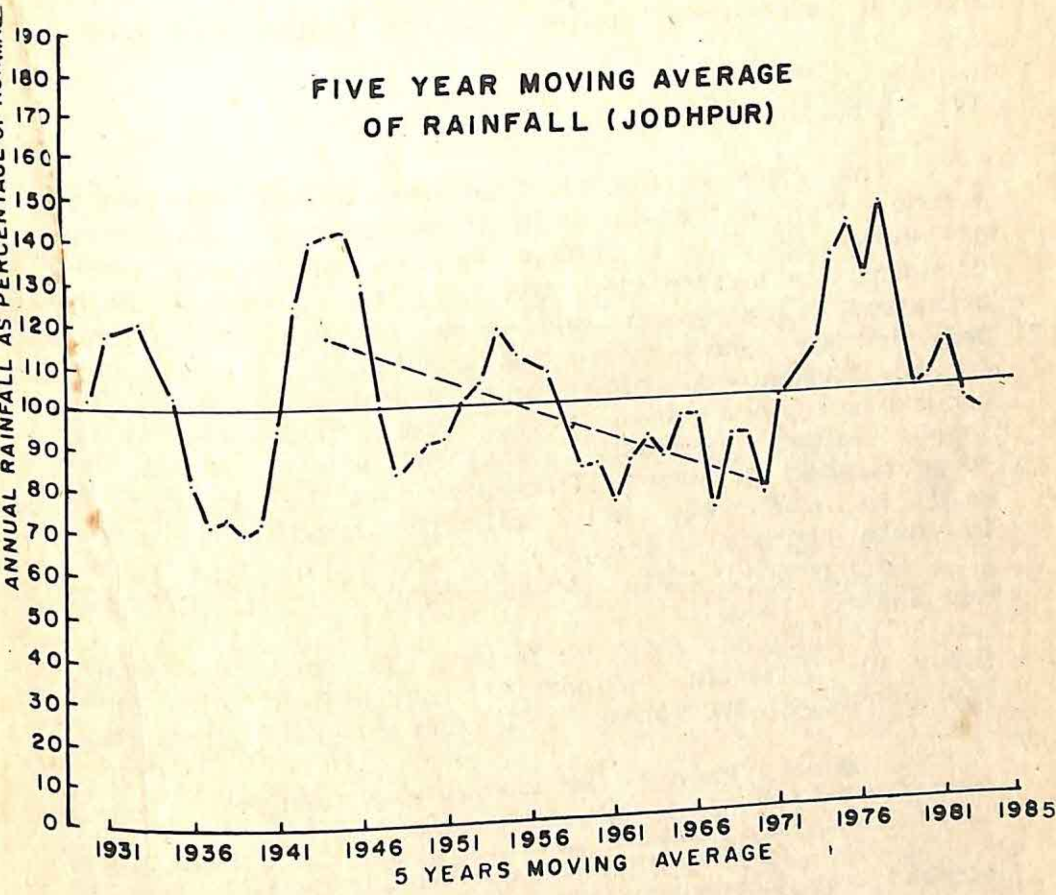


Fig 2. Trend in rainfall pattern of Jodhpur

has indicated a reserve pattern i.e. increasing trend from 1951 to 1963 and decreasing trend thereafter only upto 1970. Jhunjhunu on the other hand indicated an increased trend from 1953 onwards upto 1979 expecting for a slight decrease during 1972. In general the major part of the Indian arid zone indicate an increasing trend during the seventies (1970-79). The low rainfall during the early eighties and the two consecutive years of drought during 1984 and 1985, however, are indicators of another decreasing trend in the rainfall pattern of the Indian arid zone.

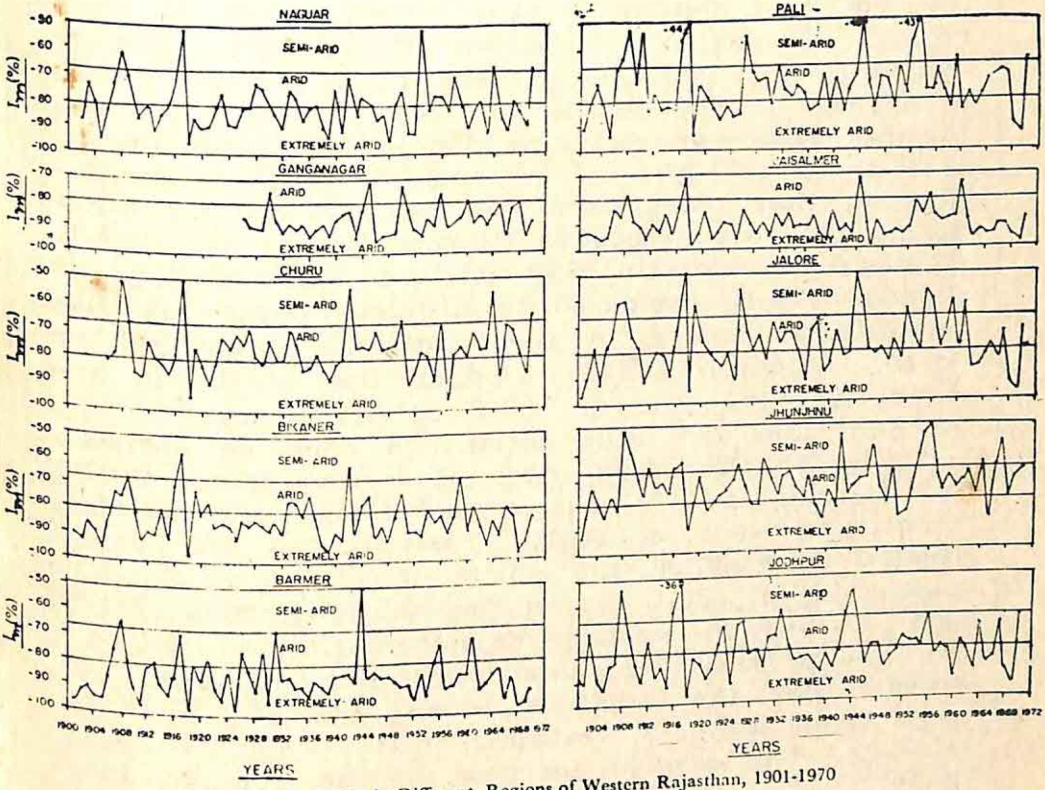
IV. CLIMATIC SHIFTS

The climatic spectrum of the Indian arid zone extends from extremely arid to semi arid conditions, as shown in Fig 3. These regions which are predominantly characterized by arid to extremely arid climates, experienced semi-arid climatic conditions only in few years when the quantum of rainfall received, remained high and moisture availability conditions were favourable. The annual moisture index values generally remained below normal in large number of years. This indicates that in general arid to extremely arid climatic conditions exist in these regions which are off-set by a large positive departure, only occassionally (Rama Krishna and Sastri, 1980).

The decadewise variations in mean moisture index in different regions of the Indian arid zone are presented in Table 1. It can be seen from the

Table 1. Decadewise mean moisture index (1901-80) over western Rajasthan

Station	MEAN MOISTURE INDEX DURING THE DECADES							
	1901-10	1911-20	1921-30	1931-40	1941-50	1951-60	1961-70	1971-80
Barmer	-86.1	-85.5	-85.8	-85.3	-81.7	-85.6	-88.7	-79.0
Bikaner	-82.7	-81.4	-84.4	-83.4	-81.4	-83.9	-86.8	-81.2
Churu	-	-79.2	-76.6	-80.2	-72.3	-81.9	-73.5	-75.1
Ganganagar	-	-	-	-89.4	-83.9	-86.0	-88.1	-81.2
Jaisalmer	-91.1	-96.1	-92.7	-91.0	-91.9	-88.1	-92.2	-88.9
Jalore	-79.1	-79.1	-79.5	-78.6	-75.5	-72.1	-84.1	-69.2
Jhunjhunu	-76.5	-74.2	-76.0	-76.4	-72.2	-71.2	-71.8	-68.3
Jodhpur	-81.9	-80.3	-80.6	-80.5	-77.9	-79.9	-81.8	-75.4
Nagaur	-79.1	-82.2	-81.2	-81.9	-81.8	-79.5	-81.2	-72.1
Pali	-73.8	-76.4	-78.0	-77.0	-73.5	-71.2	-77.4	-72.7
Sikar	-74.8	-62.8	-71.4	-67.1	-67.4	-70.3	-74.0	-59.5



Climatic Shifts in Different Regions of Western Rajasthan, 1901-1970

Fig 3. Climatic spectrum of the Indian arid zone

above table that the mean moisture index was highest at Barmer, Bikaner, Ganganagar, Jalore, Jhunjhunu, Jodhpur, Nagaur and Sikar during the recent decade 1971-1980 indicating that the moisture regime during this decade was in general better over a large area of western Rajasthan. Compared to the moisture regime during the decade 1961-70 which has been the deficient decade in the recent times in many regions of western Rajasthan, it is interesting to note that only at Churu there is a slight increase in dryness in the decade 1971-80. A gradual increase in the value of moisture index from the decade 1931-40 to 1971-80 can be noticed at Jhunjhunu indicating that this region has become slightly moist during the recent decades (Ramana Rao et al., 1984). A sharp increase in the moisture index during the decade 1971-80 compared to previous decade is discernable at Jalore in the south and Sikar in the north. Krishnan (1977) studied the shifts in the moisture index line of -80.0 upto the decade 1961-70 and observed that there has been an eastward shift in the moisture index line near Jalore during the decade 1961-70 and concluded that the desertic conditions were spreading eastward in the Jalore region. Studied on the shifts in the mean moisture index line of -80.0 during the recent decades 1961-70 and 1971-80 in western Rajasthan (Fig 4) in comparison to mean moisture index line, however, indicate that the moisture index line of -80.0 has once again shown a westward shift during the decade 1971-80. The gradual increase in the moisture index from the decade 1921-30 onwards at Jalore (-79.5) upto the recent decade of 1971-80 (-69.2) as can be seen from Table 1 show that the large departure in the 1961-70 decade was an anomaly during that particular decade only, as otherwise, a gradual increase in moist conditions can be observed to prevail in the Jalore region also.

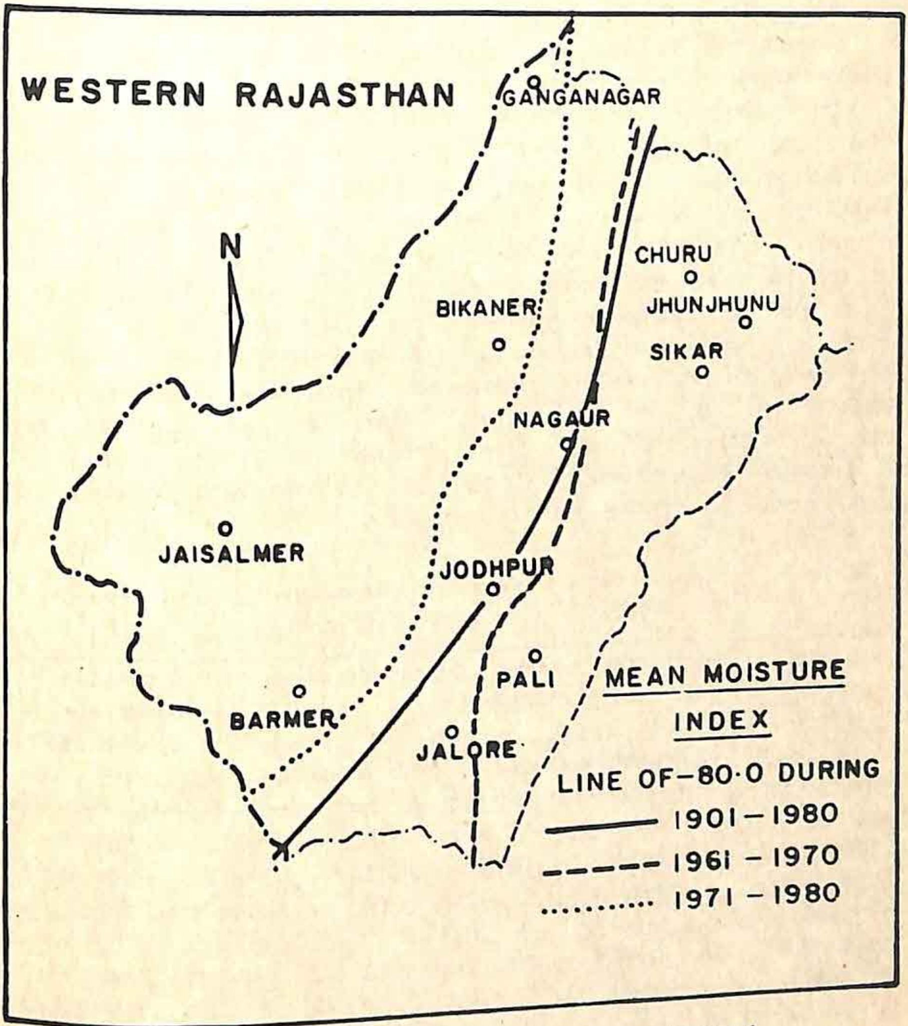


Fig 4. Shifts in the mean moisture index line of - 80.0 over western Rajasthan.

V. DROUGHTS AND DUST STORM ACTIVITY

The Indian arid zone which is characterized by low and erratic rainfall distribution often experiences droughts of moderate to severe nature. Analysis of the probabilities of occurrence of meteorological droughts in the different regions of western Rajasthan during the past 80 years (1901–1980) are presented in Table 2. A perusal of the table indicates that the probability of occurrence of drought is highest in Jaisalmer followed by Ganganagar, Jodhpur and Pali. However, all the districts in western Rajasthan indicate probabilities of more than 50 per cent showing thereby that one out of two years experience drought of some intensity or other in these regions. The probability of occurrence of severe droughts (M_3-rainfall less than 50 per cent of normal), however, indicate highest percentage of 30 at Jaisalmer and 25 at Barmer and Jalore which shows that these western parts of Rajasthan experience droughts of severe nature at least once in three to four years.

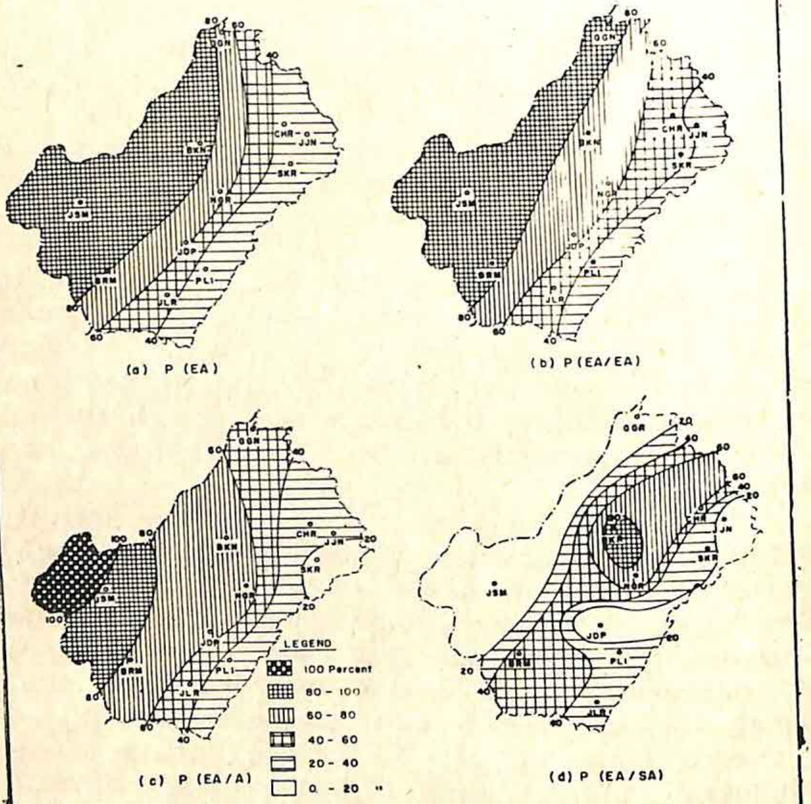
Table 2. Probabilities of occurrence of meteorological droughts (1901-80) over western Rajasthan.

Station	Percentage frequency of occurrence of droughts M_0 (No drought)	M_1 (Mild)	M_2 (Moderate)	M_3 (Severe)	Probability of occurrence of drought(%)
Barmer	50	12	13	25	50
Bikaner	46	15	23	16	54
Churu (1906-80)	41	31	16	12	59
Ganganagar (1926-80)	36	25	20	19	64
Jalore	41	23	11	25	59
Jodhpur	39	24	16	21	61
Jhunjhunu	43	28	20	9	57
Jaisalmer	34	16	20	30	66
Nagaur	39	25	20	16	61
Pali	44	19	26	11	56
Sikar	47	23	14	16	53

For understanding the drought vulnerability of different regions in western Rajasthan, the probabilities of occurrence of extremely arid conditions

P(EA) and EA conditions followed by EA, A (arid) and SA (Semi-arid) conditions are worked out and presented in Fig. 5. The similarities in the pattern of P(EA) and P(EA/EA), however, indicate that the probability of occurrence of EA conditions almost remain the same even when EA conditions prevailed during the preceeding year. The pattern of P(EA/A) and P(EA/SA), however, indicate that the chances of occurrence of EA conditions following an year with 'A' conditions are highest in Jaisalmer region and are low in Sikar region on the eastern side (Rama Krishna et al. 1984). The chances of EA conditions following SA conditions, however, are higher in the region comprising Bikaner, Churu and Nagaur districts. The above study clearly show that extremely arid conditions is a recurring feature of the extreme western part of the Rajasthan state and thus indicates the vulnerability of this region to further desertification during extreme drought years.

The dust storm and wind erosion activity in the Indian arid zone has a good relationship with the seasonal rainfall. A study of the frequency of dust storms and monsoon rainfall over western Rajasthan indicates that whenever the rainfall in a particular year decreases sharply and is very low, the subsequent summer season experiences a sharp increase in the frequency of occurrence of dust storms (Krishnan, 1977). This finding has considerable significance on the mechanism of soil erosion and desertification process. This is so because drought conditions result in sparse vegetation which with excessive human and biotic interference for fuel and grazing, deteriorates fast and causes soil surface to become loose and over trodden thus making it accessible to be blown off more easily and vigorously by wind action. This results in the occurrence of large number of dust storms, dust raising winds and dust hazes during the subsequent summer season. Thus drought years have multiplier effect on desertification process. The intense drought spell during the decade 1961-70 in the arid zone thus could have



(a) P (EA)

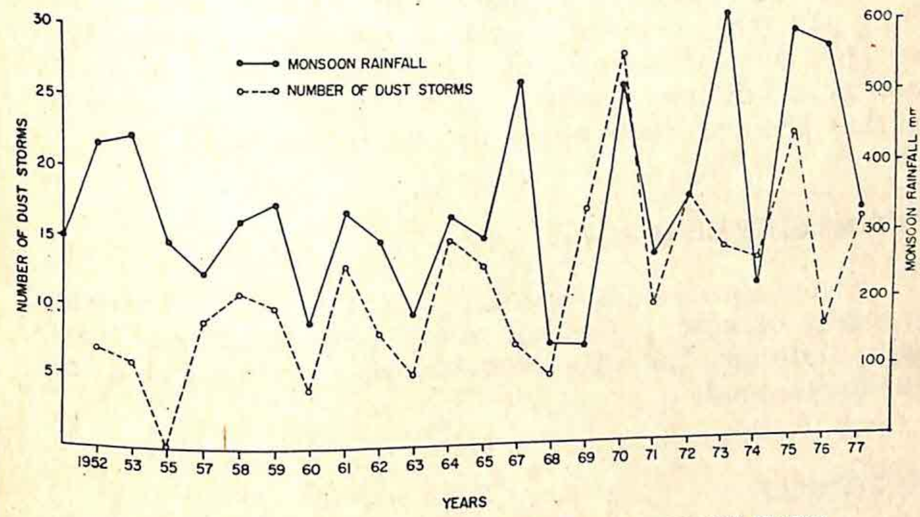
(b) P (EA/EA)

(c) P (EA/A)

(d) P (EA/SA)

Fig.5 PROBABILITY AND CONDITIONAL PROBABILITIES OF OCCURENCE OF EXTREME ARIDITY

Fig. 5



RELATIONSHIP BETWEEN FREQUENCY OF DUST STORMS AND MONSOON RAINFALL

Fig. 6

contributed to some extent in the deterioration of the desertic conditions in the Indian arid zone as can be seen from the association between the monsoon rainfall and dust storm activity at Jodhpur which was at its peak in summer of 1970 following the two severe drought years of 1968 and 1969 (Fig. 6). The present spell of drought during 1984 and the current season of 1985 also seems to point towards conditions leading to accentuation of desertification process once again in the Indian arid zone.

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7

HUMAN RESOURCES ASSESSMENT IN ARID ZONE OF RAJASTHAN

S.P. Malhotra

I. INTRODUCTION

Man has been one of the most important and active agent of biotic interference in the fragile eco-system of the Indian arid zone. Over-grazed lands, shrinking forests and eroded agricultural fields show the imprints of man's activities on the environment. The crucial problem of the region is thus of human ecology and in the context of integrated resources surveys for the resource use planning, the assessment of human resources forms one of its important components. Recognizing this, the socio-economic investigations have been undertaken to establish the resources inventory for the sedentary, nomadic and semi-nomadic population of the region by adopting different techniques and methods suitable for different situations. For establishing the macro-level data base pertaining to the human population, land use, cropping pattern and livestock population etc. the data available in various census reports, revenue records, livestock census reports have been collected, compiled and analysed. Since the population inhabiting the arid zone could be categorized in two distinct groups viz. settled and nomadic, socio-economic surveys were separately planned for them.

II SOCIO-ECONOMIC SURVEYS

A. Settled population:

Socio-economic studies among the settled population have been undertaken as part of the multidisciplinary integrated surveys in the areas where basic resources surveys have been undertaken. The study places emphasis on the understanding of the existing socio-economic structure and cultural aspects of the population. Though various methodologies viz. observation, interview and case study have been found useful, the most effective method for establishing such a resources inventory has been by the application of the schedule method. Looking to the setting and the administrative set up in the region these surveys had been initially carried out at the Community Development Block Level. Since it was neither considered feasible nor appropriate to conduct a census study, a study of representative sample was resorted to. Community Development Block had been taken up as the unit of study and a household for investigation purpose. A three stage simple random sampling procedure with village level workers circle as the first stage unit, a village in the selected village level circle as a second stage unit and a household in each selected village as the ultimate sampling unit has been adopted. All the households of the sample village were enumerated and a 15% of the total households selected by simple random sampling from each village. Schédules were filled in from the heads of the sample households. The data on five broad aspects generally considered necessary have been collected. The first relates to the features of the population with regard to age, sex, marital status, education and occupational distribution. The object here is to describe the nature and type of use of human resources. The second aspect relates to cultivation-size of agricultural holding, extent of fragmentation, extent of crop yield, disposal of farm produce, agricultural expenses incurred, agricultural practices followed, labour utilization on farm, the extent of adoption of agricultural innovations and extent of unemployment. The object here is to give a programme of agricultural development of the region. Another important economic aspect being investigated is the role of animal husbandry in the economy of the region. The points being studied here are the nature and type of livestock kept, extent of sale of livestock and livestock produce, expenses incurred over livestock and extent of shortage of fodder. r. The information so collected forms the base for recommendations, related to the improvement in livestock wealth, better management of livestock and disposal of livestock produce. The fourth aspect is a study of the household industries, extent of labour engaged, products made, their disposal, and their catchment area which enables a proper assessment of the present state of the industry and what needs to be done to enhance its potential. The fifth aspect deals with the extent of indebtedness, sources of credit and the role of Institutional and traditional organization in the same. The object here to assess the credit needs etc. for planning purposes.

The data collected through schedules have been put to tabulation, analysis and interpretation. To supplement the informations collected through schedule, individual and group interviews have been held with the representative cross section of the population. For the purposes of interview, information outlines or interview guidelines have been prepared in advance. A sample of the information outline on the settled population is enclosed. It may be observed that this provides scope for collection of information on various aspects like land, agriculture, animal husbandry, other sources of livelihood, social and cultural aspects, environmental factors, form of settlements and rehabilitation measures. Additionally, all available secondary information pertaining to human and livestock census, land use, cropping pattern were collected through different local sources like revenue records etc. The information so collected has been later integrated with the information collected through Basic Resources Survey of the area and the land transformation plans prepared.

As a result of our later experience about the arid zone society being more homogeneous, the size of sample of households was reduced from 15 to 10 per cent. Still later it was realised that the Integrated Natural Resources Surveys will be more meaningful if taken up on the basis of landform units rather than on the basis of the administrative boundaries alone. The merits of this shift have already been discussed by the Basic Resources Survey team.

A spatial integration of biophysical and socio-economic data based on biophysical land unit approach has therefore, been adopted currently. This approach is designated as 'Population and Land Use' study approach. Here again stratified random sampling proccedure has been adopted. First the district (Universe) has been demarcated into approximate L.F.U. (Stratas) e.g. the Jodhpur district included (i) Hills, (ii) Rocky surfaces, (iii) Buried rocky surfaces, (iv) Gravely and Flat old Alluvial Plains, (v) Sandy old alluvial plains, (vi) Young alluvial plains, (vii) Sand dunes, (viii) Flat and sandy interdunal plains, (ix) Saline Depressions. The villages having overlapping LFU's were excluded for socio-economic survey purposes. One village from each LFU (Strata) has been selected by the method of simple random sampling in each Tehsil of the district. In each sample village all the heads of households were enumerated and then 10% of the total households were seleccted by the method of simple random sampling. Schedules are applied to these sample households and interviews held with the representative cross section of the population. The information collected is integrated with the information collected by the Basic Resources Survey for formulation of the report of the district.

B. Nomadic population:

The nomadic groups of arid zone may broadly be classified in four different groups, the pastoral nomads which include Raikas and Sindhis, the trading nomads which include Banjaras, Ghattiwala Jogis and Gowarias, the artisan nomads which include Gadolya Lohars, Sattias and Sansis and the miscellaneous type of nomads like Nats, Kalbeliya jogis.

In the past the nomads performed an important complementary function in the economy of the region but in recent years, however, due to changes in the political, social and economic set up the source of livelihood of nomads has received a set back. The opening up of means of communication has reduced the importance of distribution activities by the trading nomads. The shrinkage in the extent of grazing lands due to extension of cultivation has created difficulties for the cattle breeder nomads. The villagers are no longer dependent upon those nomads who render specialised services. To assess the attitude of the sedentary population towards the visit of the nomads a survey was conducted and the findings showed that sedentary population, in general, do not welcome the nomads for various reasons. This rupture of relationship of mutual dependence between the nomads and the sedentary population made it imperative to think about framing of suitable policies for the welfare of nomads.

Socio-economic survey of the different categorizes of nomads has, therefore, been taken up with the following broad objectives.

i) To study the history of nomadism and the factors which have influenced it through the decades.

ii) To study the different groups of nomadic population and their present role in the economy of the region.

iii) To study the pattern of economic organization of the nomadic population and the socio-economic factors associated with their nomadism.

iv) To study the nature of nomadism and the migratory habits, route of migration and nomadic life of the groups.

v) To study the social organisation of the nomads and the role of different socio-economic and political institutions.
vi) To study the values, practices, beliefs and other cultural factors of the nomads.
vii) To study the problems of the nomads; and
viii) To examine the best ways and means of rehabilitating the nomads after evaluating their economic role in the region.

Due to inherent difficulties in the census count of the nomads and also the availability of the universe at one time, the method of quota sampling has been resorted to for the purpose of schedule filling. Additional to the schedule, the application of geneological method has proved very useful for collecting informations pertaining to their socio-economic life, particularly, with regard to their kinship structure which is so important for introducing any change in their socio-economic life. Indepth interviews from the representative cross section of the population were also resorted to this case for collection of detailed information on the aspects of animal husbandry, cultivation, other sources of livelihood, social and cultural aspects, environmental factors and rehabilitation measures. The information outline providing guiding questions was prepared in advance for use during interviews.

Based on the above socio-economic survey reports for the Banjaras (the trading nomads), the Gadoliya Lohars (the artisan nomads) and the cattle breeders of Anupgarh Puqal region (Pastoral nomads), have so far been finalized. The sedentarization schemes so formulated have provided leads to the Central Planning Commission in plan formulation for the nomadic and semi-nomadic population.

Additionally, several other specific purpose surveys, like the "Impact of irrigation on socio-economic life of inhabitants", "Diffusion of Agricultural Innovations", "Social Aspects of Desertification", "Socio-cultural prespectives of Land Reforms", "Micro-economic village studies" etc. have been conducted which provide a very useful information in formulation of any plans for the region.

III. FINDINGS

I. Population characteristics

Spread over an area of 208 thousand sq.kms. the Rajasthan arid zone (consisting of 11 *districts of western Rajasthan) has a population of 13.40 millions (1981). The region has an average density of 64 persons per sq.km. (1981) and is one of the most thickly population deserts of the world. The growth rate of population (1901-1981) in the arid zone of Rajasthan (excluding Ganganagar district where the rise has been mainly due to immigration of population) was 294% as compared to the Rajasthan State (231%) and of the country as a whole (187%). Similarly, within the arid zone of Rajasthan the percentage increase in population during the period 1901-81 has been 279%, 262%, 219% in the region receiving annual rainfall of less than 12" (excluding Ganganagar district), between 12"-16" and above 16", respectively.

The present age and sex composition of population and their marital status further revealed high potentialites of expansive future growth of population. Being fully aware of the dangers of getting wiped out due to high mortality, specifically during famine periods, the arid zone society had built in high fertility norms in their culture. Though the mortality, specifically the infant mortality has been controlled to a significant extent the high fertility norms still continue. Early marriage and begetting of children are integral parts of the social ethos of these people. Any deviation from the established norms is looked down upon as an aberration

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* The eleven districts are Barmer, Bikaner, Churu, Ganganagar, Jaisalmer, Jhunjhunu, Jodhpur, Nagaur, Sikar, Jalore and Pali.

and as wholly incompatible with the social fabric of the society. Divorce is a rarity, if not altogether unknown, and widowhood soon culminates in remarriage except for among *Rajput, Brahman* and *Mahajan* castes. If the birth rate does not fall, the present gap between births and deaths will further widen and the region will be faced with an inevitable population explosion. Family planning programmes undertaken in the region 'after independence have yet to make any inroads. due mainly to their inherent weakness in terms of negligence of cultural variables which are mainly responsible for creating chain of resistances. It may be emphasised that the obstacles to small family norms are not primarily technological but sociological. Unless the ancient prejudices, deeply ingrained beliefs and traditional cultural practices are taken into account it will deprive us of the sources of support to any family programmes and lead us to centres of resistance.

2. Settlement pattern

The settlement pattern constitutes predominantly dispersed homesteads and this provides greater benefits for raising livestock and in agricultural operations. However, there is much lesser use of ccommunity facilities and the net work of service institutions normally do not reach the dhanis (dispersed settlements) due to inherent difficulties created by inadequate communication facilities. This suggests scope for . organising intensive surveys and researches for bringing about effective improvements in human settlements compatible with the socio-cultural values and for making better use of local materials to make the traditional abodes comfortable.

3 Cultural Integrity and Resource use.

Resource use being the decisive factor of the pattern of their living, the population of Rajasthan's arid zone is divided into two major groups, viz.

the nomadic and the sedentary. The pastoral nomads inhabited the extreme arid areas considered unsuitable for cultivation and engaged themselves in animal husbandry, supplying livestock and livestock products to the sedentary population in exchange for the cereal foods that were produced mainly by the agricultural castes. The other types of nomads also catered to the needs of the sedentary population in return for grains (Malhotra, 1971). The sedentary population, by and large, lived in villages which were self sufficient units except for the materials supplied by the nomads operating in the region.

Each type of the two populations were further broadly grouped on the basis of their traditional occupation. There was a definite division of labour, a pattern of exchange relationships and a distributive use of the eco-system within nomadic groups, between the nomadic and sedentary populations and within the sedentary population. The traditional system of cultural integrity and resource use has largely broken down. There is increasing overdependence of population on agriculture and the man land ratio is fast declining. It is, therefore, necessary to develop avenues of employment other than agricultural and also to encourage and make use of the traditional institutions rather than to truncate the same.

4. Agriculture

Inspite of the poor soil fertility and the scanty and erratic rainfall cultivation is the major occupation of the people in the arid and semi-arid parts of Rajasthan. The average size of land holding in the region is almost double than that of the state. The land distribution, however, is uneven and there is a concentration of land holdings in the hands of richer farmers.

The per capita availability of total land (geographical area) has declined by about 35% during

1951-71. While taking the current trends of population growth into view this is likely to further decline substantially by the turn of the century. studies conducted of diffusion and adoption of improved technology by the rural population have revealed that it has so far made only a small leeway in the arid Rajasthan. As a consequence more and more lands have been brought under plough as is evident from land use statistics. The net area sown had increased by 19.6 per cent during 1956-57 to 1966-67 by an additional 3.3 per cent from 1966-67 to 1976-77. During the period of 20 years (1956-57 to 1976-77) the net sown area had increased by 23.60 per cent. The area under less intensive use of land decreased by 10.7 per cent during the period 1956-57 to 1966-67 and by an additional 5.1 per cent during the period 1966-67 to 1976-77.

5. Animal Human Relations

The high mortality among the livestock also used to take away a substantial lot of the family herds. The arid zone society had, therefore, developed a tradition of considering it prestigious to possess a large number of livestock. Quantity over quality was preferred as the periodic high mortality used to bring forth a balance between the livestock population and the grazing resources. Like the growing human population the livestock population has increased from 13.4 million in 1956 to 19.0 million in 1977. The desert area possesses some of the best breeds of cattle, sheep, goats, camels etc. The pressure of livestock on the grazing lands, however, is acute and there is a perpetual shortfall of forage requirements. The production from livestock is consequently low.

To have effective and balanced use of the eco-system, and for utilising different types of grasses, shrubs, tree leaves etc, the households used to herd a mixture of animal types including cattle, camel, sheep, goats etc. The importance of goats, acccording to the farmers; lies not merely in the returns this hardy animal gives to its owner, but also in its role in the raising of sheep. Goats often act as foster mothers to lambs as well as assist the shepherd in grazing and herding the sheep. Also, in case of any attack by wild beasts it is only the goats which bleat and give an instant indication to the owner about the attack. The rate of mortality among sheep is comparatively higher than in goats during scarcity conditions. It is a common saying among the desert people that "Oont chodde aakra aur bakri chodde kankra" ie. during scarcity conditions, the camel will only leave the pebbles. Calotropis while the goats will only leave This implies that the goat can survive on the most scanty vegetation. The goat also acts as a poor man's cow.

6. Vegetation-Human Relationships

Due to over-cultivation, the feed-back regeneration process of trees and shrubs is being hampered by the cultivator, for he maintains a bare minimum tree-shrubs population in the crop field, and rest is uprooted, resulting in lowering the woody biomass production.

The requirement and over-increasing demand is huge and over exploitation of the vegetal resources is inescapable. The older people in the villages admit that during the course of years the number of trees and shrubs has gone down steadily and not even 35-40 per cent of what was available 30 years ago has been left over.

7. Credit and Indebtendness

Credit facilities, interest rates and food grain procurement prices are almost uniform for the country, though the returns from investments, besides being risky, are much lower in the arid zone. More often than not, the crops in the region fail and the savings accumulated over a number of years can rarely meet the future capital needs of investment in different occupations.

The Mahajan, the traditional money lender, still remains to be the chief source of credit and quite substantial part of the debt incurred by the farmers is due to the high rate of compound interest on the loans charged by him. Co-operative societies have been functioning in some villages but these have so far been unable to replace the money lender. One of the chief reasons for this failure is that these societies give loans only for productive purposes and not for other purposes, including the socio-religious needs of the community. Also the foresight of the people for advantages of controlled credits and their punctual repayment is lacking.

8. Nomads and Nomadism

Famines of different kinds, namely *akal* (great famine), *jalkal* (scarcity of water), *tinkal* (scarcity of fodder) and *trikal* (scarcity of fodder, water and grain) have been of common occurrence in the region. To cope up with such unfriendly climatic and environmental conditions, the inhabitants have been resorting to nomadic and semi-nomadic life. They are not a separate ethnic group and do not have a separate territory with exclusive rights and economic framework.

The nomadic groups of the arid zone may be broadly grouped into four categories, viz. (a) the pastoral nomads (*Raikas, Sindhis, Parihars, Billochs* etc.), (b) the trading nomads (*Banjaras, Ghattiwala Jogis,*and *Gowarias,)* (c) artisan nomads (the *Gadoliya Lohars, Sansis* and *Sattias)* and (d) miscellaneous type of .normads *(Nats, Kalbeliya Jogis)*.

In olden days the nomads performed an important complementary function in the economy of the region. In recent years, however, due to changes in the political, social and economic set up of the tract, the sources of livelihood of the nomads have considerably contracted.

Each nomad group is associated with some kinds of livestock which make indiscriminate use of the meagre available grazing resources and defeat the local soil conservation measures. In the changed economy, the nomads are meanace for the whole society and their sedentarization is desirable. The opening up of means of communication has reduced the importance of distributive functions of the trading nomads. Shrinkage of grazing lands due to extension of cultivation has created difficulties for the cattle breeder nomads. Villagers are no longer dependent upon the nomads who rendered specialised services in the past. Studies have shown that the sedentary population, in general, do not welcome the nomads for various reasons.

This rupture of relationship of mutual dependence between the nomads and the sedentary population points to the need for the formulation of a policy for the welfare of the nomads.

Detailed rehabilitation schemes have been prepared for the *Banjaras* (the trading nomads), the *Gadoliya Lohars* (the artisan nomads) and for the nomadic cattle breeders of the Anupgarh-Pugal region of Western Rajasthan, keeping in view their present cultural values, kinship structures and other important social and economic factors.

Studies have shown that the *Gadoliya Lohars* desire sedentarization in small agnatic groups within their own *choklas*. Sedentarization programmes on this basis will ensure the continuity of their symbiotic relationship with sedentary population through marketing facilities for the articles fabricated by the nomads. Settlements in small, scattered groups will make it easier for the Government to allot land for cultivation to the Gadoliya Lohars. Moreover, such sedentarization should rule out any change of fueds occuring amongst the households of different clans. The Gadoliya Lohars should, therefore, be settled in bands of small kinship groups within their own choklas or their present areas of movement.

Nomadic Banjaras should be sedentarised tanda-wise i.e. in small kinship groups. Settled Banjaras work in agriculture and animal husbandry, trading in cattle and salt. The tanda should be treated as the unit for settlement purpose. Any approach to the Banjaras should be through their Mukhias who are not their best spokesmen but also the best media for communication with them.

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8

MONITORING DESERTIFICATION AND ENVIRONMENTAL IMPACT ASSESSMENT

R.N.P. Sinha

I. INTRODUCTION

Global concern about the extension of desert conditions has been an offshoot of the global concern about the deterioration of the environment as a whole. The United Nations Conference on Human Environment was held in Stockholm in 1972 to consider environmental assessment, which has come to be known as Earthwatch in its global application. The Earthwatch was meant to have four functions: (i) evaluation and review to provide the analysis to identify the gap in the knowledge and action; (ii) research to provide new information or new interpretation of old information which may lead to better understanding of environmental problems and thus provide guidance to decision making process; (iii) monitoring to gather in a continuous and systematic fashion certain data on specific environmental variations, and to evaluate each data to determine and predict important short and long-term environmental trends; and (iv) information exchange to provide data to scientific and technological communities the world over so that decision making at all levels may have the benefit of the best information available at the appropriate time and in the most usable form.

A few months after the Stockholm Conference the United Nations Environmental Programme (UNEP) was established with its headquaters in Nairobi. UNEP began to develop and apply its theoretical concept into practical terms, the most marked progress being made in the field of monitoring and information exchange. Thus the Global Environmental Monitoring System (GEMS), the International Referral System (INFOTERRA) and the International Register of Potentially Toxic Chemicals (IRPTC) were established. With the help of a global network of monitoring system coordinated through the efforts of the UNEP, but executed by a number of UN Agencies and other bodies, the GEMS had tried to establish the means to understand rapidly and correctly the changes brought about in the global environment by the action of man. It has set seven goals for itself-(Tolba, 1982,p.15.)

1. Establishment of an expanded human health warming system.
2. Assessment of global atmospheric pollution and its impact on climate.
3. Assessment of the extent and distribution of contaminants in biological systems, particularly food chains.
4. Assessment of the critical environmental problems relating to agriculture and land and water use.
5. Assessment of the response oт terrestrial ecosystems to the human pressures exerted on them.
6. Assessment of the state of marine pollution and its impact on marine ecosystem.
7. Improvement in the monitoring of the factors necessary to understand and forecast natural disasters.

It is an extensive system and it will take many years to establish itself in its entirety. But one thing that soon became obvious is that it does not clearly specify the growing problem of the deserts. So, when the great drought (1968-73) and its consecutive consequences swept through the Sahel stretching across Africa along the southern margin of the Saharan desert, the world attention was dramatically focussed on the accentuation and extension of desert conditions. This led to the convening of the United Nations Conference on Desertification at Nairobi in August, 1977.

II. DESERTIZATION AND DESERTIFICATION:

The term desertification was thus used for the first time in this context. Mostafa Kamal Tolba in his opening address to the Conference stated, "Subject of desertification, fragmented among a great variety of disciplines, lacked structure and coherence. Indeed the very word itself, a neologism that has not yet found its way into the dictionaries, lacked - and still lacks- a definition that satisfies everyone. Precise standards are yet to be formulated for measuring desertification and gauzing its advance" (Tolba 1982 p 72).

Before this, the term desertization was already in use to indicate the areas that have become similar to deserts, the desert being defined by the Conference as 'regions where vegetation is scarce or absent as a result of lack of precipitation or of edaphic drought'. The term 'desertification' indicates that areas have been made into desert by man (from the Latin *facare*= to make, Vink,, 1983, p.178). The Conference defined the term desertification as 'the intensification or extension of desert conditions; it is a process which induces a reduction of biological productivity with consequent reduction of the biomass of plants, of grazing capacity of this land for cattle, of the yields of crops and of human-beings'. Desertification occurs predominantly along the borders of deserts in areas where the average annual precipitation is in general between 100 and 200 mm and rarely comes above 300 mm in any year.

It is clear by now that while desertization is due mainly to natural causes like climatic accidents, aeolian action and natural edaphic deterioration, the main cause for desertification is found in population increase which leads to rapid extension of agricultural land over increasing dry areas, overgrazing by the livestock, destruction of vegetation for fuel, and increased establishment of wells for drinking water resulting in disturbance of water balance. No less responsible may be the over enthusiastic developmental activities like opening of mines, setting up of industries and building of dams and reservoirs and siting settlements which may disturb the ecological balance thereby extending the margins of the deserts or accentuating the existing desert conditions.

The Nairobi Conference on Desertification produced, among other documents, a World Desertification Map on a small scale (1:25 mill.) based on Soil Map of the World (FAO/UNESCO 1971) and on other data and criteria. The following phenomena have been shown in the legend of the map:

(i) degree of desertification hazard (very high, high and medium)
(ii) vulnerability of land to desertification processes like sand movements, deflation, sheet wash, accelerated run -off, gully erosion, deposition, salinization and alkanization.
(iii) high human and animal pressure.
(iv) bioclimatic zones: hyper-arid, arid, semi-arid, and sub-humid.

According to the report attached to it over 3 mill. Km² of the world have a very high degree hazard of which over 1 million are in the arid zone, 2 mill. in semi-arid zone and some 100,000 in sub-humid zone.

III. MONITORING OF ENVIRONMENT AND ENVIRONMENTAL IMPACT ASSESSMENT

Monitoring has usually been seen not as an independent exercise but as closely related to decision making process. Monitoring separated from the decision making process will be ignored. Therefore, making monitoring system as the essential link between information and decision is crucial in the administrative and political structure of the decision making system. On the basis of this understading the essential roles of monitoring have been specified as :-

1. determining how far a given policy is succeeding in meeting objectives.
2. detecting important environmental and economic problems at an early stage and to determine if the best use is being made of available opportunities.
3. determining how far the control implemented is meeting the assumed costs and benefits, and
4. determining what modifications, if any, are necessary to improve control system performance (Bennett and Chorley, 1978 p. 259).

Monitoring of environment is the foundation on which the new concept of Environmental Impact Assessment (EIA) has been built. The EIA was conceived in the U.S. in recognition to the practical limitations of cost-benefit analysis. The National Environmental Policy Act of 1969 (NEPA) required an Environmental Impact Statement (EIS) for all major federal actions significantly affecting the quality of human environment. EIS had to give certain statements on the impact of a proposed action, any unavoidable adverse impacts, alternatives to proposed actions and the relationship between local short-term uses of the environment and the maintenance of long-term productivity, and finally, any irreversible or erretrievable loss of resources. Several countries of the world-Germany, France, Ireland, and now India as well, have also followed the American example and some form of environmental impact analysis is required by law.

EIA is specifically designed to look at both nature (characteristics) and distribution (spatial spread, timing and effects on particular group of society) of impact that might result from a proposed action, programme or policy initiative. The EIA deals with those effects that are not readily quantifiable in money terms and hence which can not be inserted d on a cost-benefit balance sheet. An EIA should contain the following - (Turner and O'Riordan, 1982, p. 387):

1. A description of the proposed scheme and of relevant alternatives including doing nothing at all.
2. Prediction of the nature and magnitude of environmental effects, both positive and negative, preferably for each of the alternative studies.
3. An identification of how such effects are valued by representative section of society.
4. A testing of impact indicators as well as of the methods used to determine their scales of magnitude and relative weights.
5. A prediction of the magnitude of these impact indicators and of the total impact of proposed project and relevant alternatives.
6. Recommendations; for project acceptance or rejection plus advice on how to reduce or remove the most serious of the impacts as measured or as a socially valued, or recommended for adoption of the most suitable alternative scheme.
7. A programme of inspection both during project constrution and after project completion to assure that environmental effects are minimised.

Thus EIAs are more than mere description or analysis, they contain statements about how people judge the seriousness of effects and hence how their political representatives who finally make the decision should weigh-up the relative merits of different arrangements advanced by different interests in society. The EIA should also help the decision maker weigh-up the importance of different arguments.

IV TECHNIQUES

There are numerous possible techniques for evaluating the impact of major proposed activities on the environment, which can be applied in the context of monitoring the process of desertification. Any sort of developmental project is likely to disturb and even disrupt the fragile desert ecosystem, initiating further desertification. Therefore, before starting any project EIA must be made. A limitation of space permits the presentation here of only five techniques, four reviwed by Mitchel (1979) and one by Turner and O'Risordan (p. 393-6).

1. Check lists method:

This technique has also been called by others as Background Data Analysis or Baseline Inventory, a descriptive method. This is a simple method and is used during the initial stage of identifying major areas of concern. The check lists detail a range of primary impacts to be considered. It starts from an understanding of the physical and biological pro- cesses and parameters which are likely to be affected by a proposed scheme. Categories of impacts are usually sub-divided into different areas of concern such as ecology, pollution, aesthetics and direct effects on man. Ideally, they should also cover an assessment of the interests and preferences of the different social groups in the area concerned, for any major proposal is bound to affect their values and attitudes.

In practice, however, this seems to be an almost impossible task. The investigation may last for many years to understand the nature of the process and trends. Therefore, to simplify and shorten the process sampling methods are used. This involves judgement as to what is likely to be affected, what is environmentally important or politically relevant. This determines the quality of the final analysis.

2. Overlay method:

In this method a series of maps of the area are prepared on transparent paper. This involves the following steps:

(i) The study area is divided into sections based either on a grid system or certain features such as topography, geology, soil, land use, population etc.

(ii) Data are collected for the chief characteristics of the area such as - topography, geology, climate, soil, hydrology, demography, housing, water distribution, animal and plant life etc.

(iii) Then positive, negative and neutral effects of the proposed scheme on each of these characteristics are estimated. The estimated impacts are mapped on transparent overlays, the low impacts being indicated by light shading and high impact by dark shading. Each environmental characteristic will have one map which will indicate the nature, intensity and spatial distribution of the impact.

(iv) Lastly, the transparencies are laid one over the other. This will give the composite picture of clusters of high and low impacts.

This process permits the use of only a few maps at a time, but computer mapping may help in comparing a larger number of maps at a time.

The greatest merit of this method is its attractive visual display, more so if made in colours. This is obviously the best suited to persons in geographic profession.

3. Matrix Method:

It is quite common to prepare a matrix to identify the impact of any proposed project on the environment. This involves, first, the identification of all the actions that are part of the project. Then it is visualised how each actions will influence every aspect of the environmental characteristics or conditions. Thereafter, the magnitude and importance of each impact are assessed. This is the most vital part of the exercise and most difficult as well. The basic problem here is that there is no means of deciding which impact is important and which not, and what will be the magnitude of the impact. Immediately arises the question who should decide the creteria by which the effects are to be assessed. A representative committee consisting of informed people from various walks of life representing a cross -section of interests may do this work. This committee may fix weightage ranging from 1 to 10 both for the magnitude and importance, 10 representing the greatest magnitude of importance and 1 representing the least (but no zero). A simple set of criteria can be established to assist in the determination of these numbers, such as (i) beneficial and/or adverse (ii) short term and/or longterm, (iii) reversible and/or irreversible (iv) direct and/or indirect. (v) local and/or strategic (Haynes, p.392). Now, for each action on each environmental characteristic the number indicating magnitude of the impact is placed on the left hand side of slash and the number. indicating the importance on the right hand side as shown in the table below.

Table I: An Environmental Matrix:

Environmental Characteristics	Proposed Action	Deep Drainage	Ploughing of peatland	Enlargement of fieldsize
Ecology	Plant species diversity	10/10	10/10	4/3
	Endangered Plant species	7/10	8/10	4/2
	Endangered insect species	8/10	7/10	4/2
Amenity	Intimacy of landscape	2/7	6/8	7/9
	Distribution of trees	5/8	4/3	8/9

After Turnner and O'Riordan

No attempt is made here to add the numbers. The numbers indicate the major areas of concern. This type of matrix gives an idea of the possible impact so that planning authorities are warned of the possible hazards, and remedial measures may be taken. The text accompanying the matrix discusses the significant impact from this point of view.

The problem with this matrix approach is that it is relatively inflexible and hence can only cope with obvious effects. In many cases the obvious impacts may result in other changes which can again be studied with special treatment. Besides, some aspects of social impacts such as noise, visual intrusion, loss of sense of satisfaction in knowing that certain patch of scenic beauty has not been left undisturbed are beyond numerical specification.

4. Network analysis:

This method of environmental impact assessment is more sophisticated than the three discussed above in that it recognises the chain of interactions between project activity and the environment. For example, introduction of canal irrigation in the desert area may have a direct effect for the better on the plant community (first order impact), but some of the effect may also be due to changes in the water table, such as waterlogging, or due to changes in the micro-climate - increased humidity and influx of birds which may harm standing crops (second and third order impacts). The network analysis starts with a list of activities which would arise from a proposed project and attempts to trace the subsequent series of impacts and their interactions. This method is most useful for assessing single proposals where the impacts are relatively simple.

One stumbling block in case of network analysis is the lack of information about cause and effect. The outcomes are also not weighted as to their importance.. But this type of analysis is easy to follow and can be of great assistance in informing nonexperts and elected representatives. such as members of public

5. Quantitative Method:

In this method all the impact variables are reduced to numerical values so that an aggregation of all such values may give an assessment of the degree or amount of impact. So the first exercise in this case is to determine weights according to the estimated importance among a fixed number of weighting units. The following procedure may be followed to fix the weights:

(i) A group of informal individuals is explained the concept of weighting and the use of ranking.

(ii) Each individual is asked to rank environmental impact categories(such as ecology and amenity) in decreasing order of importance. He assigns a value to the first category on his list and then decides the value of others as compared to the first, the estimates varying in decimals between 0 and 1.

(iii) Within each category all the impacts are similarly ranked and given decimal values.

(iv) Averages are computed over all individuals for all categories and all detailed impacts.

(v) The group result is revealed to the individuals and the experiment is repeated with the same group and also with a different group.

(vi) The final weights are fixed in proportion to the averaged scores, out of a fixed number (may be 100).

Once the weights are fixed, they are related to process. Thus, for each of the impacts an index of environmental quality is developed, by taking the following steps:

1. Information is obtained on the relationship between the environmental variable and the quality of environment (for example, environmental quality increase with the diversity of plant species).
2. The axes of a graph are drawn wherein the horizontal axis ,bears the values of the environmental variable and the vertical axis bears the values of the environmental quality (varying between 0 and 1).
3. The environmental quality associated with a certain value of environmental variable is determined, and that point is marked on the graph. This process is repeated for the various values of the environmental variable. Finally, all the points are joined to make a curve representing the relationship between the variable and environmental quality.
4. Several persons representing different interests in society are asked to repeat steps 1 and 3,, and the curve is averaged to give a group curve.

5. This curve is shown to all participants and they are asked to review if there are large variations. The group curve may then be modified.
6. Steps 1 and 5 are repeated with a separate group of specialists, to test for reproducibility.
7. All the above steps are repeated for all selected variables.

The process is, no doubt, tedious and laborious, but the crucial point is that "While the weighted exercise gives a good sense of importance of various key environmental characteristics, it is the relationship of likely impact to these weighted environmental characteristics that provides the decision maker with a proper understanding of the socially valued implications of various courses of action" (Turner and O'Riordan).

All these environmental impact assessment methods help to highlight the major impacts and pinpoint issues which are of concern to the community involved. From the point of view of simplicity and adaptability, geographers may opt for the overlay method as that involves mapping which is their exclusive field, though other methods also may be adopted with profit. The need is to apply these methods to the study of impact of the new projects in the desert environment so that steps can be taken to stop the intensification or outward march of desertification in India.

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'DESERTIFICATION'-BY SOILS APPROACH

A.S. Kolarkar and Nepal Singh

I. INTRODUCTION

As a sequel to the sufferings of people due to disastrous droughts in the late 1960s and early 1970s, in the Sudano-Sahelian zone and on the initiative of a number of developing countries of Africa which suffered it, the problem of desertification on a global scale was brought forward for the first time at 29th session of the United Nations General Assembly in 1974. Later, to create a global awareness of the problem, United Nations Conference on Desertification was held in Nairobi in 1977, calling for discussions on varied point of views of various countries and presenting a Desertification map of the world. The general concensus was:(a) a considerable area has become desert since the dawn of civilization, and (b) many vulnerable areas are even now being turned into desert. Further, the process of desertification has intensified in recent decades and it threatens the future. The main cause had been recognised as intensive and indescriminate human use of the land, water and plant reasources which is ecologically inappropriate to the natural conditions and the special features of arid and semi-arid lands. It was also felt that it is a very complex process and the knowledge about the scientific problems involved in it is either inadequate or totally lacking. It was decided to bring to the attention of the people of the world and their political leaders in particular, the extent of desertification in the world, its causes and also its appropriate remedies.

II. DESERTIFICATION

The term 'desertification' is relatively new to the community of soil scientists, though they have been familier to the words like "Soil deterioration" or "Soil degradation" which implies decline in quality of soils and ultimately in productivity of soils. Despite the 1977 United Nations Conference on Desertification, there seems to be no generally accepted defination of the term, although its ultimate grave effects are widely accepted, and appreciated.

In a note supplied along with world map of desertification (FAO and UNEP 1977) the term is defined as "The intensification of or extension of desert conditions; it is a process leading to reduced biological productivity, with consequent reduction in plant biomass, in the land's carrying capacity for livestock, in crop yields and human well being". It was felt by Rozanov (1982) in U.S.S.R that such a definition of substance and problem, though acceptable for political and administrative purposes, is inadequate from technical point of view as it is not an operative definition in scientific terms. He proppsed it therefore as "Desertification is a process of irreversible change of soil and vegetation of dry lands in the direction of aridization and diminition of biological productivity which in extreme cases may lead to total distruction of biospheric potential and conversion of land into desert". He explained the terms used in it as follows:

Irreversible change:- Change of soil and vegetation that requires either man's ameliorative interference or a very long (decades or centuries) natural process for restoration of it to former condition.

Dry land:- Territory in tropical, subtropical, semi-arid, arid or seasonal sub humid climate.

Desert:- Dry land which is almost devoid of vegetation and developed soils.

Biological productivity:- Annual production of biomass.

Aridization of soil:- Decreased ability of soil to supply plant with available water.

Aridization of vegetation:- Increase of xerophilous species in vegetation together with general dimintion of vegetation density and biological productivity.

Dregne (1978) in USA, defined the term "Desertification is the process of impoverishment of terrestrial ecosystems under the impact of man. It is the process of deterioration in those ecosystems that can be measured by reduced productivity of desirable plants, undesirable alterations in the biomass and the diversity of the micro and macro fauna and flora, accelerated soil deterioration and increased hazards for human occupancy".

It is obvious from above definitions that many point of views still exist concerning the exact meaning of desertification. However, there are no two openions on the fact that i) It is a complex process involving man, plant, soil, animals. ii) it is a process which has a number of stages from slight to severe. iii) as a result, it affects and effects in decline in the land productivity in terms of biomass/crop production. iv) soil factor; which is a general media for all plants to grow is a basic componant to be considered in desertification.

III. DESERTIFICATION CAUSES AND PROCESSES

Land degradation on range land, or grassland, woodland or forest land and crop lands begins with deterioration of the vegetative cover due to overgrazing, wood cutting, and improper cultivation (Kassas 1970). Once the plant cover is disturbed, soil degradation occurs in the form of accelerated wind and water erosion, soil compaction, surface soil crusting, loss of soil humus and soil fertility, salinization and water logging (Dregne 1982). Salinization and water logging have attracted most attention only in relation to irrigated land productivity, but they are also problems in some dry land farming areas (Vander Pluym 1978; Dregne and Zartman 1980). Accelerated water and wind erosion is a prime factor in affecting soil conditions and reducing productivity. Most obvious example is the removal of rich fertile top soil and exposure of argillic B horizons in developed soils. The important soil characteristics like infiltration rate, moisture content; structural stability, soil density, available nutrient level, etc, are all altogether different and inferior in this new surface soil than in the old one. At many places, the underlying hard strata or rocky material gets exposed. It is therefore certain that eroded soil could never again be the same as the original soil even if erosion were reduced. Further, therefore, there is no question of doubt that a very severe wind erosion condition known as blow-outs, when an argillic or calcic horizons or gravelly or rocky strata is exposed to surface, has brought about a permanent change in arid region soils. If this happens through water erosion, it is the same in effect, with that process too.

The major desertification processes recognised by Dregne (1982) in North America are basically soil degradation processes. They are water erosion, wind erosion, both associated with loss of soil fertility, compaction and soil crusting, which can be called as physical degradation, and salinization. Soil degradation processes recognised by him in South America are water erosion, wind erosion and salinization. The major causes found for these in south America are, over grazing, excessive wood-cutting, dryland cropping of lands subject to frequent droughts, and poor drainage of irrigated lands. All these have exacted a heavy stall in the arid zones of South America. In North America three major causes or instances described are i) over grazing in desert grass lands ii) salinization of irrigated lands and iii) Wind erosion in crop lands in the Great Plains during protracted droughts of the 1930s.

The Major processes recognized by Balba (1982) in north Africa are also the same and in order of their seriousness i) Wind erosion, particularly sand movement and formation of dunes, ii) Water erosion iii) Soil Salinization. The causes to accelerate the processes are also the same. In an exhaustive review of the conditions in west Africa, however, Adu (1982) states point of views that there had been the evidences of climatic change and the desert was encroaching from south to north, In all instances, the evidence of progressive desiccation and encroachment of the Sahara on the Sudan pointed to the failing wells, shrinking rivers and lakes, river beds being chocked by drifting sands, waters becoming increasingly saline, crop failures and southward migration of agricultural communities. It was however also realised that desiccation in the area was not wholly because of climatic or natural factors but to a lesser extent also due to incalculable harm brought by shifting cultivation in fragile ecosystem, absence of crop rotation or manuring. Thus, the causes recognised are i) frequent droughts ii) improper land use practices, iii) Bush fires and lack of forest managements. While discussing desertification in India particularly the past and future of Thar desert, Mann(1982) attributes the escalation of desertification in this region to the causes a) climatic deterioration b) escalation of human and livestock population resulting in over grazing and cultivating marginal lands, accelerating erosion, particularly wind erosion. He has also emphasised that detrimental activities of this kind are still continuing and cropping on marginal lands has increased during the past two decades by about 54% and as a result area of pasture has declined. Dhabariya (1985) has brought to the focus indescriminate deforestation activities and degradation in the Aravali ranges. As a consequence of such a biotic interference of over grazing and felling of trees in forest lands, about 4.35% of the western Rajasthan has already been severely affected; 72% of the desert has been categorized as highly vulnerable and 19% moderately vulnerable to various deterioration factors (Mann 1982).

Thus, it can be summarized that the major causes to set in the processes of desertification as seen in various continents are i) climate change towards desication or frequent occurances of droghts ii) over grazing of range and pasture lands, degrading vegetation and soil iii) shifting cultivation or dry land cropping in marginal lands, again destabilising soils, particularly during droughts. iv) deforestation and mismanagement of forest lands etc.

The processes of soil degradation involved are i) water erosion, ii) wind erosion, iii) soil salinization iv) soil compaction and crusting or soil physical degradation.

IV ASSESSMENT AND MONITORING DESERTIFICATION

Monitoring of a process or a phenominon requires carrying out systematic permanent or periodic ground observations and measurements. Assessment and monitoring of desertification requires a coordinated approach by a team of specialists of various disciplines like vegetation, soils, hydrology, geology, agronomy and so on and so forth. In many cases, desertification may be induced not by one but by many causes or it may be provoked by one factor and intensified by others. Analysis of ecological situation and inter acting factors will provide a solid basis to study its causes, processes involved and the extent of it in each climatic or ecological zone or region; and it will facilitate to monitor it further. As a first step, two major kinds or process of desertification should be recognized. i) Natural, ii) Man induced.

In the case of natural desertification processes the causes may be either climatic or geological (tectonic) uplifting of land, descending ground.waters, accumulation of salts in basins with no outflow etc. However, in case of man induced desertification, which is of our concern, causes may be varied like cutting of forests and shrubs, overgrazing of pastures, inappropriate seasonal use of pastures, ploughing of soils unsuitable for agriculture, use of ecologically inappropriate technology in agriculture, use of ground waters without recharge, change in hydrology of a territory, irrational use of water resources etc. These causes and their areas are first to be recognised and analysed in a given region. At second step, the quantitative determination of two inter-connected parameters may be taken as the basis for the diagnosis of desertification process 1) Degree of aridization of vegetation. 2) degree of aridization of soil. Further, like any dynamic natural process, desertification may then be established and assessed by comparative analysis. Two substantially different methods may be used i) comaparison of the state of territory at different times or periodic intervals. This will help to establish presence of desertification in the region as well as degree and rate of the process. (2) Comparison of the state of two different territories in the same climatic region and ecological and soil zone at the same time. In this method, comparative geographical analysis based on hypothesis of correspondence or similarity of geographical sequence of phenomenon is used. However, in this case fact of desertification may only be established and the degree of its manifestation in some relative units may be determined. Its rate, however, can not be determined.

V SOIL DEGRADATION MAPPING APPROACH TO DESERTIFICATION

Desertification is a form of degradation itself and the same processes are involved in soil degradation and desertification. However, in the latter, additional emphasis is given to vegetation cover, its degradation and to grazing animals. At many places, soil degradation and vegetative degradation are contributary factors to each other. Vegetational aspect in desertification, nevertheless, will be dealt by plant ecologist separately. Here, we will consider and confine to soil degradation only, and its mapping with soil maps, as proposed by FAO, UNEP, UNESCO (FAO 1979).

Soil degradation is a process which lowers the current and/or the potential capability of soil to produce goods or services. (FAO, 1979). Soil degradation processes are phenomenon that cause a decrease in the quality of soils to produce crops or plants. The processes recognised are i) Water erosion ii) wind erosion iii) Excess of salt accumulation of salinization iv) chemical degradation- leaching of bases and build up of element toxicity v) physical degradation- build up of adverse physical properties, including porosity, permeability, bulk density, structural instability, crusting etc. vi) biological degradation- increase in humas mineralization. These processes are known for sure to result in the loss of soil productivity. Lack of firm relationships between the rate of soil degradation by one single process with resultant actual loss of soil productivity makes it very difficult to asses actual rate of soil degradation; and even to study the combined effect of more than one processes. Their mapping in this context, becomes still a difficult task. The methodology proposed by FAO, therefore, seems to have a good promise for adoption and making some data base, on the areas affected, and being affected.

The principal on which it is based is that the land is attacked by forces of climate, and it is referred to and quantified as aggresivity of a particular climate. The soil/land (ecosystem) has a varying degree of resistance to these forces. The balance between these two determines the 'risk of soil degradation'. Human action can either increase or decrease the natural resistance of the soil/land to degradation forces, so that the present "rate of degradation" is determined by the way the present land use modifies the balance. The present state of soil with respect to each process is known through soil surveys.

VI APPLICATION OF FAO METHODOLOGY TO GUHIYA CATCHMENT - A PART OF UPPER LUNI BASIN:-

a) General information of the area:-

Guhiya, catchment lies within Lt.25°-45' and 26°-10'N and Lon. 72°55' and 74°-15'E. It covers total area of 3051 Km^2. Annual average rainfall is 396 mm while annual potential evaporation is 1699 mm. Mean maximum and minimum temperatures during summer are 41°C and 27°C and during winter are 24°C and 6°C respectively. Monthly average wind speed varies from 1.22 m to 4.30 m per second, maximum being during May and June. Data on physi- cal factors like, landform, topography, soils, veg- etation, hydrology, land-use etc. was available in a comprehensive report on Integrated Survey Report of the catchment (CAZRI 1 32). Twenty one soil series were distinguished in the area and soils were map- ped in 29 soil mapping units. Standard soil survey methods (IARI 1971) were adopted in this integrated survey.

b) Interpretations for soil degradation mapping

As first step, use was made of climatic data and formulae proposed in the method to find out climatic aggresivity; under each degradation process. The formulae used, the resultant values of climatic aggresivity and their ratings is given in table 1.

Table 1 Climatic indices used for various soil degradation processes, estimated values of climatic aggresivity to soil degradation.

Soil degradation process	Climate index	Climatic Aggresivity to degra-ation	Rating of aggresivity
1. Water erosion	$\frac{12}{\Sigma}\quad\frac{P2}{P}$	40t/ha/yr	Moderate
2. Wind erosion	$\frac{12'}{\Sigma}\quad V\frac{3}{100} \times \frac{PET-P}{PET}xn$	52t/ha/yr	High
3. Soil salinization	$\frac{PET}{p \times 10}$	o.28 mm nos/yr	High
4. Physical degradation	$\frac{1}{100} V \Sigma\frac{P2}{P}$	0.10 increase in A.D.g/cm^2/yr	Moderate
5. Chemical degradation	$\frac{P-PET}{2000}$	-0.65 pH units/yr	Not operative
6. Biological degradation	$\frac{HI}{10}$	34% humus decay/yr	Very high

The data indicates that climatic aggresivity in biological degradation is "very high"; in wind erosion and salinization, it is 'high', in water erosion and physical degradation "Moderate" whereas, chemical degradation is not operative in this climate.

At second step, to find out the 'risk' of soil degradation in each of the soil unit mapped, and under each degradation processes, the values of topographical factor and approprite soil factors were introduced in the value of climatic aggresivity. In soil factor, while soil texture of profile was considered in all the processes, other soil characteristics like soil erodibility, soil structure, drainage, diagnostic horizons, silt/caly ratios, $CaCO_3$ contents etc were also taken into account of evaluating soil factor. Value of topographical factor is dependent on slope of the land. The parametric values for these factors are already given in the methodology. Thus, the value of climatic aggresivity, multiplied by values of topographical as well as soil factor would give the 'risk' of degradation under each process on each of the soil unit mapped. Those values, when checked against catagory ratings, give the classes as 'very high', 'high', 'moderate' and 'none' risks. Thus, the resultant is the map of 'Risk of Soil degradation'. There are now only 13 units.

Further to arrive at the "present rate" of soil degradation, values attributed to various land uses were introduced by multiplication to the value of "risk" each unitwise under each process. If present land-use is forest, the kind of forest, its density in the unit etc, were considered. Similarly, if the unit is a crop land, whether irrigated or under arable farming etc. was seen and appropriate values assigned. As a result "Rate of soil degradation map" was prepared.

The "present state of soil degradation is primarily based on actual surveys. There are the units indicating well conserved soils, and there are other areas which are moderate to very highly eroded through forces of water, while still other eroded by wind. There are large areas, affected by salinization while others are having very dense and compact soils, indicating physical degradation. Large areas are biologically highly degraded with very poor humas content and therefore highly responsive to manuring.

Table 2, indicates the distribution of per cent areas in Guhiya catchment under various categories of soil degradation under different processes. Thus, a data base on soil degradation aspect can be made. This data further can be integrated with data and observations of other specialists like plant ecology, hydrology, social sciences with village data, and thus can be converted into a desertification data. Periodic monitoring in more vulnerable areas of high risks can also be made.

Besides this, such maps can also be useful to take timely and appropriate measures in priority areas to check further soil degradation or to cambat desertification and to conserve soil quality and soil environment properly for the future generations. In conclusion, it can be said that although desertification is a very diversified and far reaching physical, biological and environmental degradation in a region, the soil,which forms a basic media for any plant growth, its study and monitoring with respect to its quality and the degradation, forms the very firm basis for the study and monitoring of desertification.

Table 2. Percent area distribution in Guhiya catchment under various categories of soil degradation under different processes.

Soil degradation process	Risks of soil degradation				Rate of soil degradation				Present state of soil degradation			
	None to slight	Moderate	High	Very high	None to slight	Moderate	High	Very high	None to slight	Moderate	high	very high
Water erosion	56	43	-	1	76	24	-	-	38	30	22	10
Wind erosion	-	74	26	-	28	45	27	-	66	14	7	13
Salinization	31	17	33	19	28	52	10	10	56	22	12	10
Physical degradation	41	59	-	-	78	22	-	-	39	48	13	-
Biological degradation	-	-	42	58	-	29	54	17	-	16	54	30

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DESERTIFICATION IN WESTERN RAJASTHAN

S.K. Saxena

I. INTRODUCTION

Fast depletion of vegetal resources and gradual degradation of various ecosystems in western Rajasthan can closely be correlated with the increasing population pressure of men and animals. A perusal of both will provide a vivid picture and circumstances which lead in the reduction of land productivity. Undue biotic pressure manifest itself in the form of desertification.

II POPULATION STRUCTURE

(a) Total human population of western Rajasthan, constituting eleven districts, is 13.4 million (1981 census). The average population density of whole Rajasthan is 100 persons/sq.km. while western Rajasthan showed 87.7 persons/sq.km. Jaisalmer district with its vast area (38401 sq.km) recorded lowest density (6 persons/sq.km) whereas Jhunjhunu touched fairly high population density (201 person/sq.km). Indian desert is well known for its high population density in the world. Other deserts of the world show as low as 4 persons/sq.km. Over past thirty years (1951) the population of Rajasthan has become more than double. Rajasthan State register higher growth rate (32.38 per cent) as against overall National growth of 24.75 per cent. The western districts have registered an abnormal growth which may be due to higher birth rate and decline in death rate.

(b) Like growing human population the livestock population has increased from 10 million in 1951 to 19 million in 1977. On an average 2.35 ha/head of grazing area is available in Jaisalmer district which is highest while Pali registered 0.03 ha/head of available grazing area. High animal population put severe grazing pressure in the available grassland/grazing areas, causing their extreme degradation. Not only this other fallow land, protected areas and cultivated land etc. become the grazing target for the animals. In case of protracted droughts or famines, the non-availability of grazing material make the situation quite acute. Even the nonpalatable material is removed from the ground leaving them as bare patches. The percentage distribution of livestock in arid areas of Rajasthan has shown 65.6% goat and sheep, 29.8% cattle, 3.8% camel and 0.6 per cent others.

The population explosion in the desert tract has compelled its inhabitants to bring more land under plough. This has resulted in the shrinkage in the hectarage of marginal lands like grazing land and wastelands etc. (Mann et al. 1977). Wood is the main source of energy in the rural areas. Thus with increasing population the demand for fuel wood also increases. This had led to unwise exploitation of available vegetation. Besides this the destruction of wood increases many fold when many cottage industries like dying and printing industries consume local wood. Continuous flow to feed the requirement of these industries, bring about fast depletion of fuel wood resources.

Charcoal making is a very old industry. It has a high consumption value in urban areas. The poor people and tribe men convert the forest wood into charcoal. Good forest trees like *Anoqeissus pendula* (Dhau) *Acacia senegal* (Kumat) *Prosopis juliflora* (Vilayati babool), *Acacia nilotica* (Babool) etc. have become the main target for charcoal making. Thus all the unprotected hilly region containing these species have now completely degraded. Only protected hills witness these trees. The greed of people have compelled them to extricate even the root system of these species and convert into charcoal. In Bikaner district the extraction of phog *(Calligonum polygonoides)* roots is invariably carried out by its inhabitants. Bikaner township has continuous supply of *phog* roots. Root digging lead to loosening of sandy soil or rocky fragments. Thus accelerate the wind and water erosion hazard. In desert area the fuelwood demand is ever increasing and the over exploitation of vegetation is inescapable. This process lead to desertification.

III MECHANISM OF DESERTIFICATION

Desertification may be defined as packages of processes which bring about changes in the ecosystems of arid and semi-arid zones causing reduction in productivity, alteration in the density of lifeforms, reduction in biomass, acceleration in soil degradation and other hazards. Excessive and inproper landuse during protracted droughts accelerate the process of desertification. Thus this phenomenon involves an interplay of climates, edaphic and biotic factors. Recently the ecologist and environmentologist have warned the planners and politicians that excessive desertification process is in progress in arid and semi-arid parts of the country. Thus the problem has acquired a national significance. U.N. in one of its statistics have also assessed that 50-70 thousand sq.km. of fertile land become unsuitable for utilisation due to desertification impact.

According to Rapp 1974, the following are the common mechanism of desertification.

1. Expansion and intensification of landuse in marginal lands during wet years. These action

include excessive grazing, ploughing and cultivation of new land and wood collection around new settlement".

2. Wind erosion during the next dry year or water erosion during the next maximum rain storm."

Arid ecosystems are known as fragile and these may easily be made imbalance due to men's interference. Gradual ecological changes in large arid tract brings about an alteration of micro-climatic status of the land. This degradation process in the desert area repeats itself at many sites. All such innumerable sites when feed back the process collectively- the impact of desertification process is highly evident.

IV CAUSES OF DESERTIFICATION

The causes of desertification are as follows. Factors, problems and causes of desertification are summerized here.

1. Vegetational degradation

(A) EXCESSIVE WOOD CUTTING AND GATHERING-Over exploitation of fuelwood species causes serious land degradation. The vegetation cover which protects the soil against wind and water erosion is gradually lost. Every year large hectarege of forest is indiscriminately exploited for fuel purpose or they are cleared for cultivation purpose., When vegetation cover is reduced, it may well be replaced by almost bare ground or with undesirable plant species. here gradual reduction of top soil occur by wind and water erosion. Finally it results in unproductive land or desertified land.

(B) INCREASED GRAZING:- In this case the compactness of soil takes place near water holes, wells and along the animal pathways. Higher number of grazing animals exert more pressure on palatable grasses and forage species. Overgrazing effect becomes more pronounced. Sandy soils are exposed to fast moving winds causing deflation of sand. Such soil provide lower infiltration capacity and increased surface runoff and poor percolation capacity. Bare ground provide higher albido. All these factors enhance desertification.

(C) UNWISE LANDUSE:- Every year more and more land, due to inccreased population pressure, especially the marginal lands are put to cultivation. They greatly enhance the prospect of wind and water erosion during summer months and in monsoon period. During good rainfall year more land is ploughed for grain cultivation. All these enhance the prospects of wind erosion during summer months. Increased population pressure of desert inhabitants result in more tilled acreage every year. Here marginal lands like common grazing land, grassland, sand dunes and gravelly pediment etc. with negligible soil cover are cultivated. Their use ultimately leads to desertification. The conditions beccome more pronounced when such lands are used below 200 mm. rainfall area. Their cultivation quickly brings about ecological imbalance. The desertification effects are reflected in fast sand movement. This covers the road and adjoining fertile fields. Formation of new Barchan dunes also takes place.

(B) DEVELOPMENTAL ACTIVITY:-Many well developed vegetation sites are destroyed for the construction of factory, road, industrial development, mineral mining, construction of settlements and irrigation facilities. In all such cases the whole site gets transformed either rapidly or gradually depending upon the requirement. Mineral mining activity leaves permanent scars of desertification which cannot be removed or rectified in long span of time.

(E) SALINITY AND ALKALINITY BUILD UP:- These are the two abuses of irrigated agriculture. Salinization may occur when soils are irrigated with saline water or too little irrigation is provided to heavy soils causing salinity. Sometime natuarally occurring saline soils are irrigated which result in enhanced salinization.

Canal seepage and over irrigation with poor drainage may cause water logging in nearby soils. With the rise in water table the salts accumulate on soil surface. On evaporation of water these salts are left behind as precipitation. In Indian Desert, the temporary accumulation of river ghaggar water in many interdunal areas has caused desertification to adjoining sandy plains. In the interdune the sub-surface deposit of gypsum got dissolved by downward movement of water. Subsequently the dissolved layer of gypsum allowed lateral flow of water which later surfaced out in sandy soils converting them into marshy land. (Baropal, Dablikalan and Manakheri). In course of two years the whole marshy land was occupied by marshy plants like *Typa angustata* and *Arundo donax*.

2. Climatic factors

Low and erratic precipitation, high summer temperature (40°-47°C), low humidity (below 25%), intense evapotranspiration and poor soil profile moisture status are the main climaticc constraints in arid areas. Above conditions permit only a sparse vegetation cover. The sandy soils with 80-90 per cent coarse sands almost lack binding capacity without vegetation cover. The sand starts drifting with slight increase in wind speed (9-14 m/s). The sand storms emanate from man induced vegetational destruction and climatic aridity. Protracted droughts with heavy animal pressure on vegetal resources accentuate the desertification process.

3. Anthropogenic factors

In Indian desert, as explained earlier, over grazing by large livestock population, felling of trees and shrubs for fuel purpose, mechnical destruction of vegetation in course of major/minor mining operations, construction of dam, road and settlements etc. are the multifacet effects of vegetational degradation. But overgrazing and removal of trees and shrubs are the two major factors causing desertification. The entire micro-climate of a vegetated tract gets modified due to change in species composition, dominance, population and biomass production. Once vegetation cover is destroyed, the soil cover becomes susceptible to wind and water erosion hazards. Disintegration of sandy soils is very quick. The fertile top soils move away from the field.

V STAGES AND INDICATORS OF DESERTIFICATION

Desertification process can be grouped into two stages: (1) When desertification features are perceptible and their manifestation intensity ranges between moderate to nominal. At this level the whole process is still reversible whereas under extreme deterioration the process becomes irreversible. Viewing the above aspect some indicators are needed to assess the vulnerability of the eco-system to desertification. The indicator's may help in monitoring the actual status of desertification and subsequently allow to prepare plan to do away the desertification process. The indicators may also be grouped into (1) Physical; (2) Biological and (3) Social. All these groups of indicators are to be viewed together as one single indicator cannot provide a true picture. Few important indicators are as under:-

(1) Physical indicators:

- (a) Degree of salinity and alkalinity
- (b) Groundwater depth and its quality
- (c) Depth of rootzone of vegetation
- (d) Availability of soil crust
- (e) Organic matter contents of soils
- (f) Changes in water flow and sediment runoff
- (g) Water/wind erosion effected area.

(2) Biological indicator

They are supposed to be the chief indicator of ecosystem.

A. PLANTS

- (a) Type and lifeform i.e. distribution, structure, population.
- (b) Type of canopy i.e. trees, shrub, undershrub etc.
- (c) Type of ground vegetation i.e. grasses and weed of palatable or unpalatable nature.
- (d) Status of plant communities.
- (e) Biomass production of various storey

B. ANIMALS

- (a) Major species-natural and domesticated
- (b) Their/composition and population
- (c) Breeding aspects

(2) Social indicator

The social activities have significant impact and these are to be viewed in relation to desertification together with physical and biological indicators. Important ones are:

- (a) Population structure and number.
- (b) Settlement structure of population

(c) Landuse pattern
(d) Regional planning and management

VI VEGETATION IN DESERT ECOSYSTEMS

The following account of vegetation types with their actual potential and degraded conditions are projected here. Reduction of higher plant communities to lower status speak itself that desertification process prevails. Extreme degradation lead to bare ground. Scars of wind and .water erosionn shall continue to pronounce.

1. Forest

Saxena (1977) has described six formation in western Rajasthan out of which "Xeromorphic Thorn Forest" occur on the hills. Most of high hills scattered in western Rajasthan are protected by forest department. Isolated medium to low hills scattered in various districts are badly exposed to biotic interference. Protected hills mostly support *Acacia senegal* or *Anogeissus pendula-A. senegal* as the dominating plant community. Unprotected hilly areas .are met with degraded plant communities. Here all the tree species of fuel and timber value are removed leaving the boulders exposed. They are left to vagaries of water/wind erosion hazards. On most of the hills cushion shaped or deformed bushy structures of *Anogeissus pendula, A. senegal* and others could easily to seen. These bushyforms subsequently serve as a good source of top feed to goat and sheep. In a twenty years protected hilly site with 72 plants/ha produced 4.8t/ha of fuel wood. They provided 45.9% crown cover. Similar sites with degraded conditions exhibited 5.1% crown cover. The estimated ground vegetation biomass of above ground parts was 0.20 t/ha. Here all species represented nonpalatable material.

2. Woodlands

Shekhawati region, constituting three districts (Churu, Jhunjhunu and Nagaur) support *P. cineraria* woodlands. Here the tree density ranges between 60-120 plants/ha. They hold 25-40% crown cover during September-October. These woodland produce 23.1 t - 46.2 t/ha of fuelwood and timber. All these are well protected on individual farmer's field. The unprotected lands with *Prosopis* are generally reduced to cushion shaped structure, i.e. common grazing area/village grazing lands and wastelands etc. Here only 2.5% crown cover exists with 3.0t/ha of above ground biomass. Sandy undulating plains support *Tecomella undulata-p. cineraria* woodland with 22-40 plants/ha occupying 8-10% crown cover and 3-8 t/ha of above ground biomass. The degraded conditions are represented by *Leptadenia Pyrotechnica, Aerva pseudotomentosa* and *Crotalaria burhia*. These species produce 0.8 t/ha of above ground biomass. Highly degraded conditions are represented by inferior grass species like *Cenchrus biflorus* and *Aristida funiulata*. Soil erosion hazard becomes common when the entire land is almost bare.

"The riverine thorn forest" along the river Luni and its tributories support a woodland of *Acacia nilotica* and *P. cineraria* community. A density of 52 pts/ha with 7.2% crown cover support 3.8 t/ha of ahove ground biomass. Degradation of these land is very much restricted to common grazing lands only. *Desmostachya bipinnata* and *C.biflorus* represent a highly depauperated grassland condition of such soils.

3. Shrub lands

Majority of shrublands in arid areas are the product of biotic interference. Various habitats like eroded rocky surfaces, gravelly plains, piedmont and pediment plains of sandstone, limestone, granite, and slate etc. are scattered in low rainfall area. These plains` serve as uplands to the adjoining flat plains. Here the soil cover is shallow and are subject to water erosion. Here vegetation is comparatively poor and open, constituting "SCRUB Desert" mostly of thorny species. All these habitats invariably serve as the grazing ground. Here shrub density vary from 5-25 pts/ha, producing 0.3-0.5 t/ha of above ground biomass. Most common contributing shrubs are *Capparis decidua, Leptadenia pyrotechnica, Zizyphus nummularia. Calotropis procera* and *Acacia jacquemontii.*, etc. Majority of stabilized sand dunes are met with *Calligonum polygonoides, Clerodendrum phlomoides, A. jacquemontii, C. procera* and *Aerva pseudotomentosa*. Here the plant density vary from 7-210 pts/ha but over all biomass production hardly exceeds 0.5 t/ha of above ground biomass. The above ecosystems are quite fragile and vulnerable to degradation. They are badly exploited leaving the ground bare and few may be encountered as completely desertized. Majority of them are supporting the ground vegetation only with poor above ground biomass production (0.01-0.1 t/ha). Bare sand dunes and sandy undulating plains becomes the main source of moving sand which obstructs roads, spoil fertile land and form barchan sand dunes.

4. Grasslands

In W. Rajasthan, Gupta and Saxena (1972) have recognised seven grassland types. *Lasiurus-Cenchrus* and *Dichanthium* are the grasslands of alluvial plains. Almost all are the victim of over-exploitation. Continuous overgrazing in grasslands result in complete removal of palatable material. The degraded vegetative cover consists of less palatable or non-palatable species dominance like *Oropetium-thomeaum, Aristida adscensionis, A. funiculata, Cenchrus biflorus* and *Eraqrostis poaoides* etc. These species produce low biomass production and grazing animals also losses the body weight. Under extreme cconditions the bare soils are exposed. Continuous trempling of grazing material by the hooves of livestock proves quite damaging. Tender species virtually die while stiff and rough species persist which are mostly unpalatable. Continuous movement of animals in a grassland impaired the infiltration rate of soils and this results in increased runoff. It has been estimated that overgrazed grasslands provide maximum runoff (27.0 per cent) and highest loss (2100 lb/acre) of top soil (Shankarnarayan,1977)

Potential grasslands of *Cenchrus* produce 3.43 t/ha of above ground biomass with 8.7% ground cover and same grasslands under severe grazing stress showed 1.5% ground cover and 0.95 t/ha of above ground biomass. *Dichanthium* grasslands under protected condition exhibited 3.7 t/ha of above ground biomass with 7.8% ground cover. Overexploited grassland with non-palatable species produced 0.9 t/ha of aboveground biomass. On sandy undulating plains *Lasiurus* grasslands with protection gave 2.4 t/ha of forage with 6.0% ground cover and on deterioration 0.67 t/ha of above ground biomass was produced by *Crotalaria burhia, Aerva pseudotomentosa* and *Aristida* sp. etc. having 1.7% cover. Developed grasslannds on saline patches are dominated by *Sporobolus* showing 1.64 t/ha of above ground production and the same on degradation gave 0.5 t/ha of forage production with all nonpalatable species.

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11

ANIMAL HUMAN RELATIONSHIP AND DESERTIFICATION IN ARID ZONE

L.P. Bharara

I. INTRODUCTION

Livestock rearing is the predominant characteristic of the population inhabiting dry areas of the world. Associated with it, animal-human relationship and its role in desertification is important to a greater or lesser extent in most of the arid and semi-arid regions of the Indian sub-continent. Animal-human interactions, inter relations, conditions and consequences form the components of desertification processes in the area. Man-livestock interaction includes livestock population, composition, nature and extent of ownership, increasing tendency of adopting livestock rearing as the main or subsidiary occupation by the non-livestock rearing castes, and traditional animal husbandry practices and constraints in adopting improved animal husbandry practices and constraints in adopting improved animal husbandry practices. Pasture-livestock relationship reveals livestock pressure, the nature, extent and quality of grazing grounds, shortage of grasses/ shrubs in the lands and steps followed to cope up with these, ways to improve upon the quality of grazing grounds, rights of using them and adequacy to meet the livestock demand. Livestock in relation to ecological adjustment revealds livestock migration - its nature and extent, routes followed, reasons of migration, type of migrating herds, advantages and difficulties during migration, livestock mortality relationship of migratory - sedentary livestock raisers and villagers. Various other aspects like social parameters of livestock migration, social organisation of pastoralists, and their human and social problems associated with their peculiar life styles influence the process of desertification and its consequences. A study of the above interactions, inter relations and conditions resulting in various socio-economic and biophysical consequences have produced more favourable conditions for desertification in the arid zone of Rajasthan.

Livestock is an important asset of the arid zone of Rajasthan. Next to agriculture, it supplements households economy. With about 50 million heads of livestock Rajasthan ranks third in India in animal wealth. More than eleven per cent of the total milk produced in the country is produced in Rajasthan. The state accounts for more than 50 per cent of the total national wool production, and is one of the principal suppliers of meat, eggs and milk to the adjoining states. It also provides sturdy draught animals to the country. Since more than 60 per cent of the livestock of the state is concentrated in the arid areas of western Rajasthan, these regions provide a major share of livestock production of the state. Therefore, the use of arid lands for livestock production is a logical one.

But these lands are most vulnerable to desertification. Desertification in broad sense means deterioration of land, water, vegetation and other natural resources under ecological stress. Deterioration may be due to natural or human activities with an objective to maximize short-term gain at the expense of long-term productivity. Animal human activity in the Indian desert, has revealed that ecological deterioration and accentuation of desertification has been occuring in the region in recent times due to the intense human and livestock pressure. The increased pressure of livestock on the natural grazing lands resulted in over - exploitation of resources leading to depletion of natural vegetation.

Desertification as an impact of animal human relationship at global level has been viewed from various angles (Jeremy, 1973; Kassas, 1975; CAZRI, 1977; Hare, 1977; UNCOD, 1977; Eckholm & Brown, 1977). Most of these have also correlated desertification with the social, economic, bio-physical and environmental factors connected with land scape changes, vegetational degradation, loss of livelihood, pastures turning into waste lands, decrease in crop productivity, etc. Various other studies (Acharya, et al., 1977; Bharara, 1978, 1980, 1982, 1986; Kalla et al., 1977; Malhotra, 1977; Mann, et al. 1977; Reining , 1978; Spooner, 1973, 1982) have dealt with the parameters of livestock influencing desertification.

A particularly important area of neglect is the livestock population, ecology and behaviour of domesticated animals in relation to the vegetation on the one hand and the cultural strategies of herding and husbandry on the other. Therefore, socio-economic, cultural and environmental factors of livestock in relation to desertification process are of great importance. With this in view the study focuses on Desertification as an impact of (i) livestock population, growth, type and composition (ii) livestock owership, produce disposal and practices (iii) livestock migration and pastoralism; nature, extent, reasons, and difficulties during migration (iv) livestock pressure, grazing grounds, its nature and extent of adequacy; Based on these the main findings support various hypotheses on the aspects of animal human relationship.

II METHODOLOGY

The study has been undertaken in the arid and semi-arid districts of Rajasthan. A multi-stage stratified sampling design was followed. First, the universe had been stratified into three tracts based on the amount of average rainfall and the mean aridity index. Rainfall influencing aridity is the chief variable inducing drought and desertification in the area. The tracts demarcated were 'A' receiving an average annual rainfall of less than 12" (30.5 cm) having the mean aridity index 84 and consisting of the districts of Jaisalmer, Barmer, Bikaner and Ganganagar. The tract 'B' receiving an average rainfall of 12" (30.5 cm) to 16" (40.6 cm) and having the mean aridity index 75 constituted the districts of Jodhpur, Nagaur, Churu and Jalore. The districts of Jhunjhunu, Pali, Sikar and Sirohi constituted tract 'C' receiving the average annual rainfall of 16" (40.6 cm) or more and having the mean aridity index 58

Secondly from each tract one district was so chosen as to represent a different ecological pattern areas of predominantly pastoral nomadism (305 cm rainfall), predominantly rainfed (30.5 cm - 40.6 cm rainfall), and raifed with irrigation facilities (40.6 cm rainfall). These representative areas comprised of three districts. Jaisalmer represents rainfed with irrigation facility. Thirdly, from each selected district representing a different ecological tract, 4 villages for intensive empirical field investigations were selected.

The selection of specific villages in a purposive sampling was based on the researcher's insight of the area and its problems. In addition to being a true representative of the distinct ecological tract, various other characteristics of the inhabited universe were also taken into consideration. The characteristics chosen were predominant communities, caste, occupational predominance, size and type of village and a Major Land Resource Unit - a subsistence resource base. The villages selected represented predominant communities - Hindu, Muslim and a Sectarian group of Bishnoi; Castes comprising of Sindhi Muslims, Rajputs, Jat, Seervi, etc.; occupational predominance like livestock rearing, agriculture, agro-livestock and caste occupation; village size - small (<150 households), medium (150-250) Large (250-300), and very large (300 and above); and village's Major Land Resource Unit like flat alluvial plain, dune-cum-interdunal plain, alluvial plain and rocky-cum-buried pediment. All these characteristics being chiefly representative of the whole universe influence directly or indirectly the socio-economic conditions of the eco-system.

All the households of the selected villages were stratified on the basis of caste and from each caste strata about 10% of the households selected for intensive interviewing by a method of simple random sampling. Fieldwork consisted of participant observation, intensive interviews and a field schedule containing open-ended as well as fixed response questions. Secondary data pertaining to population, land use, livestock and livestock migration, etc. were collected from various concerned departments for supplementing with the primary data.

III. MAJOR FINDINGS

Livestock population trend, growth, composition, type and density were found to be the chief livestock parameters influencing desertification process in different ecological regions of arid zone of Rajasthan. Of the hypotheses set up for testing the following appear to have been substantiated.

A. Hypotheses

1. Livestock population exceeds human population in the Arid zone of Rajasthan.
2. Despite climatic vageries, there is an increase in livestock population.
3. Differential ecologial pattern influencce growth of livestock population.
4. Growth of livestock population is higher in the pastoral tract as compared to the rainfed and irrigated agricultural tracts within the arid zone of Rajasthan.
5. Despite ecological differentiation, growth of

sheep and goats together is highest of all the animals.

6. Extent of cattle and buffaloes is inversely related with the aridity.
7. Occurrence of droughts and famines affects the growth and composition of livestock
8. Sheep and goats together constitue highest proportion of total livestock.
9. There is an increasing tendency of keeping large number of animals among the pastoralists.
10. Households owning cows and buffaloes increase with the decrease in aridity from the pastoral to rainfed and to irrigated tracts.
11. Households owning sheep and goats increase with the increase in aridity and decrease with the decrease in aridity.
12. Of the draught animals, bullocks, increase with the decrease in aridity while camels decrease.
13. Rearing of sheep, goats and cattle is no longer a monopoly of the traditional livestock rearing communities of arid zone of Rajasthan.
14. Livestock are sold chiefly for non-productive purposes viz. daily needs of the family.
15. Animal husbandry practices followed are traditional with regard to breeding, castration, treatment of sick animals, feeding, grazing etc
16. Socio-religious feelings and deeply ingrained beliefs towards animal life are the most commonly believed notions among the villagers.

B. Livestock verses human population

The hypothesis 'livestock population exceeds human population' seems to hold true in and within the arid zone of Rajasthan and Rajasthan state as a whole (Table 1).

Table 1: Human verses livestock population

Area	Human Population		Livestock population		Livestock/ Per capita
	No.	Period	No.	Period	(No.)
Rajasthan state	34.10 (million)	(1981)	49.48 (million)	(1983)	1.45
Rajasthan arid zone	13.40 (million)	(1981)	23.21 (million)	(1983)	1.72
Within arid zones:					
Pastoral tract	6113	(1981)	54209	(1983)	8.86
Rainfed tract	6692	(1981)	23154	(1983)	3.46
Irrigated tract	6295	(1981)	10572	(1983)	1.68

Livestock per capita was found to be higher in different ecological regions of arid zone of Rajasthan as compared to the arid zone of Rajasthan and Rajasthan state as a whole. Livestock was found to be associated with the extent of rainfall and aridity availability of grazing and fallow lands, traditional caste occupation and type of communities inhabiting the arid zone of Rajasthan. With the increase in aridity, due to less rainfall, there is increase in livestock favouring animal husbandry rather than cultivation. According to 1983 census, Livestock per capita was found to be minimum in Jhunjhunu (0.98) followed by Ganganagar (1.09), Sikar (1.28), Pali (1.58), Jodhpur (1.61), Jalore (1.63), Churu (1.74) and Nagaur (1.86); and maximum in Jaisalmer (6.76), followed by Barmer (2.85) and Bikaner (2.45). The later category of districts had lesser rainfall and higher aridity index and more grazing and fallow lands, as compared to the former catagory. Thus considerable increase in livestock population coupled with the human population revealed overstocked as well as over-peopled arid areas of Rajasthan.

Growth rate of livestock and human population was highest within the tracts of arid zone of Rajasthan as compared to the arid zone of Rajasthan and Rajasthan state as a whole. Extent of increase in both the parameters is givenn below:-

Table 2: Comparative mean annual growth rate of livestock and human population

Area	Mean annual growth rate			
	Livestock population		Human population	
	%	Period	%	Period
Rajasthan state	1.94	1956- 83	2.85	(1901- 81
Rajasthan arid zone	5.02	1956-'83	3.63	1901- 81)
Within arid zone:				
Pastoral tract	11.97	1961-'83)	4.75	1901- 81
Rainfed tract	5.49	1961- 83	2.58	1901-'81)
Irrigated tract	1.06	1956- 83	3.61	(1901- 81)

Of human population, livestock rearing is traditional functional specialisation of different castes and communities of the region. Raika is the most predominant traditional livestock rearing community. Gujjars, Rajputs, Jats, Mali and Seervi also rear livestock in addition to cultivation. The Gujjars are good at animal husbandry and graze ccattle, buffaloes and sheep. The Jats are the best farmers and cattle breeders. Various other traditionally non-livestock rearing communities like Brahmins, Meghwals, Suthars, Daroga, etc. had also taken up livestock rearing as their subsidiary occupation. Increase in livestock was chiefly due to increase in human population associated with predominance of agro-livestock; rearing communities; increasing tendency of keeping more livestock; traditionally non-livestock rearing castes adopting animal husbandry as their subsidiary occupation; social customs urging accumulation of wealth in the form of livestock viz. quantity rather than quality and substituting risks of crop failures with large number of animals.

Overstocking and leading to overgrazing are often being the consequence of a demographic increase higher than the basic productive capacities of the habitat. Thus, for the livestock raisers, the region demands both the maintenance of the habitat's productivity and a population density that does not lead automatically to the multiplication of livestock. Overstocking in the area leads to nomadic pastoralism which is inherently self-destructive, since systems of management are based on the short term objective of keeping as many animals as possible without regard to the long term conservation of land resources. The trend depicts steadily increasing stock numbers on progressively deteriorating land. Thus not only the number of head of livestock but also that of human beings assumes significance.

Analysis of data on animal-human relationship and people's responses have revealed the following causes of increase in livestock:-

Increased population of human have resulted in greater need for livestock as a means of eking out a living.

Health care programmes for animals have widely and effectively been introduced thereby reducing livestock mortality.

- Periods of favourable weather have enabled herds to grow and multiply.
- Because the only way of saving for many pastoralists is through herd - their bank account - they tend to increase herd size.
- Emergency feeding programme during drought have contributed to the build up of animal number or at least prevented a decrease.
- Pastoralists make consistent efforts in building animal populations beyond the capacity of natural resources.

C. Livestock population trend and growth

Considering growth of livestock population, the hypotheses (i) 'despite frequent droughts and famines, there is considerable increase in livestock population', and (ii) 'differential ecological pattern influence growth of livestock population', hold true.

According to livestock census of Rajasthan, livestock population in the ecological regions of arid zone of Rajasthan had increased considerably during 1951-'83 (Table 3). Increase registered from 32.48 million in 1956 to 49.48 million in 1983 giving a net increase of 52.34% in state of Rajasthan. Whereas, in arid zone of Rajasthan livestock had increased from 9.90 million in 1951 to 23.32 million in 1983 with a net increase of 135.56%. Amongst various ecological regions, pastoral tract revealed an alarming situation for the planners as it had the highest livestock growth of 263.26% during 1961-'83. In the rainfed tract livestock population had increased by 121% during the period of 1961-'83. While in the irrigated tract livestock had increased by about 28% during the period of 1956-83.

Based on rainfall data and villagers' perception of the nature of year, the year like 1951, 52, 54, 55, 57, 59, 1960, 62-63, 68-69, 1971, 72, 74, 1975-77, 1980-83 and 1984-86 were found to be severe

Table 3: Growth of livestock population in Rajasthan, Arid Zone of **Rajasthan** and different ecological regions of the Arid Zone of **Rajasthan.**

Year	Rajasthan		Arid Zone		Ecological Regions of Arid Zone of Rajasthan					
					Pastoral tract		Rainfed tract		Irrigated tract	
	No. Million	Variation (%)	No. Million	Variation (%)	No.	Variation (%)	No.	Variation (%)	No.	Variation (%)
1951	-	-	9.0	-	-	-	-	-	-	-
1956	32.48	-	13.40	+35.37	-	-	-	-	8,225	-
1961	33.51	+3.16	13.72	+2.36	14,923	-	10,482	-	-	-
1966	37.48	+11.83	16.21	+18.15	31,657	+112.14	11,229	+ 7.13	10,532	+28.05
1972	38.88	+ 3.73	16.28	+ 0.48	33,438	+ 5.62	13,971	+24.41	14,517	+37.83
1977	41.36	+ 6.38	19.02	+16.81	39,989	+ 19.59	15,191	+ 8.73	11,369	-21.68
1983	49.48	19.63	23.32	+ 22.60	54,209	+ 35.56	23,154	+52.42	10,572	- 7.01
Overall Variation		+52.34 (1956-83)		+135.56 (1951-83)		+263.26 (1961-83)		+120.89 (1961-83)		+28.53 (1951-83)

Source : Livestock Census Records, Rajasthan Revenue Board, Ajmer.

droughts and famines (250 mm mean annual rainfall) occuring during various livestock census periods reducing livestock population due to mortality and less production. Despite such recurring drought features of the arid zone of Rajasthan, the livestock had considerably increased by 35% during 1951-56; 2.36% in 1956-61; 18.15% in 1961-66 and 22.6% in 1977-83. The increase also seems to be associated with the occurrence of even one good year in a census period. The years like 1953, 1958, 1961, 1964, 1967, 1970 and 1983 were found to be actual good years accelerating growth of livestock compensating the drought impacts. Whereas, cumulative effect of droughts and famines during 1956-61, 1966-72 and onwards had hampered the growth, of livestock. Pastoral and rainfed tracts as compared to irrigated one had highest increase of 112% and 52% during 1961-66 and 1977-83 respectively. On the contrary livestock had decreased by 7% and 21% in the irrigated tract during the period of 1972-77 and 1977-83 respectively.

D. Type of livestock and growth

According to recent livestock census (1977-'83), livestock population had on an overall increased by about one-fifths in the state of Rajasthan and more than that in its arid zone. Among various types of livestock, sheep followed by goats, cattle, buffaloes and camels were the most predominant types of livestock in the area. Extent and growth of different types of livestock population differed in various regions surveyed (Table 4)

Data revealed that sheep and goats as compared to other types of livestock had increased alarmingly during the period. In Rajasthan and its arid zone, sheep population had increased by 31-35%, Goats 21-25%, Buffaloes 19-28%; Cattle 4-13% and camels 0.1.6% during 1977-83. Tractwise growth of different types of livestock population revealed that in the

Table 4: Growth of different types of livestock population in Rajasthan, Arid Zone of Rajasthan and different ecological areas of arid zone of Rajasthan during the period of 1977-'83.

Area & Year	Type of livestock					
	Cattle	Buffaloes	Sheep	Goat	Camels	Others
Rajasthan						
1977	12.90	5.07	0.94	12.31	0.75	0.26
1983	13.47	6.04	13.39	15.41	0.75	0.44
Variation (%)	+ 4.42	+19.13	+34.71	+25.18	+ 0.0	+69.23
Arid Zone of Rajasthan						
1977	4.03	1.38	6.68	6.16	0.63	0.13
1983	4.56	1.76	8.76	7.45	0.64	0.16
Variation (%)	+13.15	+27.54	+31.14	+20.94	+1.59	+23.10
Ecological tracts						
pastoral						
1977	3980	-	19697	14310	1473	529
1983	7261	20	32348	12516	1287	777
Variation (%)	+82.4	+100.0	+64.2	-12.5	-12.6	+46.9
Rain fed						
1977	1804	545	6107	6070	609	56
1983	2995	994	9534	8837	790	4
Variation (%)	+21.90	+82.40	+56.10	+45.60	+29.70	-89.30
Irrigated						
1977	3895	1012	3831	2332	18	281
1983	3065	1196	3710	2496	41	64
Variation (%)	-21.30	-18.20	- 3.20	+ 7.10	+127.80	- 77.20

Note: Livestock population in Rajasthan and Arid Zone is in millions.

the pastoral tract cattle had increased to the maximum (82%) followed by sheep (63%) during the period. In the rainfed tract there was a maximum increase in sheep (56%) followed by goats (46%), camels (30%) and cattle (22%) and goats (7%) while other types of livestock had decreased. Buffaloes which were almost non-existant in the pastoral tract during 1977, had been introduced afterwards and had increased by 82% in the rainfed tract.

Inter-tract variations concluded that amongst tracts, highest growth rate of predominant livestock viz. sheep, goats and cattle took place in the pastoral and rainfed tracts during 1977-'83. Increase in sheep and goats irrespective of the tract is not only conducive to desertification but also makes the tracts more vulnerable to desertification. it is also natural to expect a positive degree of association between the population increase and an increase in the intensity of depletion of natural grazing resources in the tracts. The constant interaction of the population pressure with a given phyto-mass will lead to the vulnerability of the eco-system and thus accentuate the desertification process.

E. Composition of livestock

Livestock composition reveals the nature and extent of different type of livestock's proportion to total livestock. Livestock composition and its change during 1977 to 1983 in arid zone and within ecological regions of arid zone of Rajasthan is given in Table 5.

Data revealed that of the total livestock of arid zone of Rajasthan (1983), sheep population constituted maximum (37.6%) followed by goats (32%), cattle (19.5%), buffaloes (7.5%), camels (2.7%) and others (0.7%). There was no significant increase or decrease in its composition during the period of 1977-'83. But the composition differed in different ecological regions of arid zone of Rajasthan. Type of land, nature and extent of population inhabiting

Table 5: Percentage composition of livestock in Arid Zone of Rajasthan and its different ecological regions surveyed

Livestock	Arid zone of Rajasthan		Percentage of livestock composition					
			Pastoral tract		Rainfed tract		Irrigated tract	
	1977	1983	1977	1983	1977	1983	1977	1983
Cattle	21.2	19.5	9.9	13.4	11.9	12.9	34.3	29.0
Buffaloes	7.3	7.5	neg.	0.1	3.6	4.3	8.9	11.3
Sheep	35.1	37.6	49.3	59.7	40.2	41.2	33.7	35.1
Goat	32.4	32.0	35.8	23.1	39.9	38.2	20.5	23.6
Camel	3.3	2.7	3.7	2.4	4.0	3.3	0.2	0.4
Other	0.7	0.7	1.3	1.3	0.4	0.1	2.4	0.6
Total	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0

the region and traditional caste occupational skill of livestock rearing were the main factors influencing number and type of livestock and its composition in a region.

In a pastoral tract composition of livestock population revealed predominance of sheep and goats together constituting more than fourfifths of total livestock during 1977 and 1983. Cattle constituted about one tenths; camel and others less than four per cent while buffaloss were negligible. A significant change had been in the composition of cattle, sheep and goats. Cattle and sheep had increased from 9.9% and 49.3% in 1977 to 13.5% and 59.7% respectively in 1983. While goats and camels decreased from 35.8% and 3.7% in 1977 to 23.1% and 2.4% respectively in 1983. There was almost no change in buffaloes and other category of livestock in the pastoral tract.

Rainfed tract had also predominance of sheep and goats together constituting 80% of total livestock during 1977 and 1983. Others like cattle constituted hardly 13%, buffaloes 4% and camels 3% only. Composition of all types of livestock had almost remained constant in the tract. However a slight increase in buffaloes was due to increase in cultivation and availability of stall feeding. Introduction of tractors for ploughing purposes adversely affected the camels used for ploughing and this further affected the camel composition in the area.

In the irrigated tract also, sheep and goats together were predominant comprising of more than half of total livestock. Cattle constituted more than one fourths and buffaloes more than one-tenths of total livestock in 1983. However, there was a decrease in cattle composition, from 34% in 1977 to 29% in 1983. Whereas increase occurred in buffaloes-from 8.9% to 11.3%, in sheep 33.7% to 35.1%; and in goats 20.5% to 23.6% during the period.

Comparison of livestock composition (1983) in various tracts revealed that cattle constituted highest (29%) in the irrigated tract. Sheep and goats together were maximum (83%) in the pastoral tract and minimum (55%) in the irrigated tract. Whereas camels constituted highest percentage (4%) in the rainfed and pastoral as compared to the irrigated one.

It is thus concluded that higher the aridity of the tract having more fallow and duny lands for grazing, higher the number of sheep and goats conducive to more desertic conditions of the area. On the other hand, higher the irrigation facility and lesser aridity with more scops for cultivation allowing lesser grazing lands, higher the number of cattle and buffaloes in the area and lesser sheep and goats.

F. Livestock pressure.

Increase in the livestock population has led to the overstocking of the permanent pastures and other grazing lands in the area. The Raikas and Sindhi Muslims-the traditional sheep and goat raisers, followed by Rajputs and Jats who had taken up sheep and goat rearing as a profitable occupation had further supported the fact of gradual shrinkage of grazing lands for the animals. This has been revealed through high density or pressure of livestock in terms of adult cattle units per ha. of any type of land-use category (Table 6).

Data revealed that in arid zone of Rajasthan, density of adult livestock units per 100 ha of permanent pastures, total grazing lands available, net area sown and total geographical area was found to be 1017, 95, 85 and 43 respectively during the year 1983. The livestock pressure in all the cases had increased from minimum 13% to maximum 23% during the period of 1977-83. Density of the livestock was quite high as compared to an optimum desirable pressure of 20 adult cattle units per 100 ha of permanent pastures and other grazing lands under these conditions

Table 6: Density of adult livestock units/100 ha of land use category in arid zone of Rajasthan and ecological regions.

Regionwise type of land	Density of adult livestock units/ 100 ha of land		Increase in livestock density % (1977-'83)
	1977	1983	
1. Arid Zone of Rajasthan			
• Total area	35	43	22.86
• Permanent pastures & other grazing lands	884	1017	15.05
• Total grazing lands available	79	95	20.25
• Net area sown	75	85	13.33
II Pastoral tract			
• Total area	30	40	33.33
• Permanent pastures and other grazing lands	552	708	35.6
• Total grazing lands available	37	50	35.14
• Net area sown	152	206	35.53
III. Rainfed Tract			
• Total area	40	61	52.50
• Permanent pastures and other grazing lands	894	1362	52.35
• Total grazing lands available	125	191	52.80
• Net area sown	58	89	53.45
IV Irrigated tract			
• Total area	38	36	-5.26
• Permanent pastures and other grazing lands	613	570	-7.01
• Total grazing lands available	77	72	-6.49
• Net area sown	76	70	-7.89

Livestock pressure differed in various tracts due to different land use parameters sustaining varied livestock pressure. Of all the tracts, rainfed tract had highest livestock pressure (1977-83) of all types of livestock on various land use categories. The livestock pressure was highest (1362 adult livestock units per 100 ha) on permanent pastures and other grazing lands of the rainfed tract whereas pressure on net sown area was highest in the pastoral tract. The reasons of comparatively lower pressure on permanent pastures, on total grazing lands and on total area of a pastoral tract, were the availability of large areas of pastures and barren and uncultivable waste lands used for grazing. In the irrigated tract, livestock pressure was comparatively less. It was 570 adult livestock units per 100 ha of permanent pastures in 1983. Due to decrease in livestock population of the irrigated tract, the pressure had decreased from 5% - 8% in all the land use categories during 1977-83. Whereas due to increase in livestock population, pressure had increased from 33% to 36% in the pastoral tract; and more than half of in the rainfed tract during 1977-'83. The reasons of increase in density of livestock were found to be' shrinkage of grazing lands due to cultivation of more and more marginal and sub-marginal lands, less fallowings, substitution of cattle with sheep and goats considered to be the most hardy livestock capable of surviving even on marginal and submarginal lands, etc.

A positive degree of association persists between the livestock population increase and an increase in the intensity of depletion of grazing lands in the tracts. The constant inter-action of the population pressure with the given phyto-mass will lead to vulnerability of the eco-system and thus accentuate the desertification process. Thus to maintain a balanced eco-system, it is recommended to have an optimum density of livestock for optimum judicious use of the grazing resources. Limited density of livestock will help in preventing deterioration of grazing lands thus maintaining its quality.

G. Livestock ownership

Livestock-raising households make a living from their animals by maintaining sufficient number of animals. Herd sizes are determined by human manipulation under low technology conditions of subsistence pastoralism, due to uncontrolled environmental stresses or disasters. The keeping of large herds is closely linked to the need to protect the household against the effects of drought or epidemics as well as to food requirements during a particular dry period. A sufficient number of animals must survive a disaster in order that the household can exist while the herd is being rebuilt. In arid zone of Rajasthan owning large herds is a traditional symbol representing socioeconomic status of the desert dwellers and is strongly associated with caste and religion. The Rajputs, Jats, and Raikas are the traditional livestock rearing communities of the arid areas of Rajasthan. Recently, non-livestock rearing communities like Brahmin, Swami, Sewak; castes serving to agriculturists - Suthar, Lohar, Kumhar; and other castes Mahajan, Nayak, Nai, Soni, Kumhar, etc. have taken up livestock rearing as their main or subsidiary occupation.

Raising cattle is the traditional occupation of the Rajputs and Jats in all the tracts, raising sheep and goats is traditionally associated with the Raika community of the area. Rajputs and Jats are also engaged in sheep and goat rearing chiefly in the pastoral and rainfed tracts. The bullocks and cows are kept in small number by the larger percentage of households while sheep and goats are kept in large numbers by a comparatively lesser proportion of households. Goats, considered to be poor man's cows, are kept by largest percentage of households in the tracts A and B.

Livestock ownership data revealed that a household on an average owned 43 heads of livestock in the area. The mean number of livestock per household came to be 72,34 and 22 in the tracts A, B and C respectively. Tract and caste-wise differences in mean number of livestock per household are given below:

Table 7 - Caste-wise mean number of livestock per household in different tracts

Predominant traditional caste group	Mean number of livestock per household Pastoral tract	Rainfed tract	Irrigated tract	Total
AGRICULTURAL				
(Rajput, Jat, Bishnoi, Rajpurohit, Seervi, Mali, Purohit, Charan)	58	59	17	45
LIVESTOCK RAISERS				
(Sindhi-Muslim, Raika, Gujjar, Ghanchi)	100	83	58	80
SOCIO-RELIGIOUS				
(Brahmin, Swami, Sadh, Bhat, Gurda, Gusai, Nath, Sevak, Joshi)	7	7	13	9
CRAFTMEN				
(Lohar, Suthar, Meghwal, Kumhar, Reghar)	17	15	9	14
OTHERS				
Rendering services to village communities (Nayak, Nai, Mahajan, Harijan, Daroga, Bavri, Sargara, Khatik, Dholi, etc.)	48	5	10	21
Total	72	34	22	43

Mean number of livestock per household was highest in the pastoral tract. Muslims - the traditional livestock breeders who were following a pastoralistic pattern of life owned highest mean number of livestock. In the pastoral tract, Sindhi Muslims followed by agro-livestock rearing caste group were the most predominant communities owning the most livestock and by implications contributing most to desertification. Of the other castes only the agro-livestock group had a large mean number of livestocck per household ranging from minimum 17 in tract C to maximum 58-59 in tract A and B. The socio-religious castes had the least number of livestock since their traditional beliefs are against rearing sheep and goats.

Of the various types of livestock owned in the tracts surveyed, cows and young stock were predominantly owned by 70 per cent and 59 per cent of the total households respectively in all the tracts. Sixty per cent owned goats, 40 per cent bullocks, 30 per cent buffaloes, 27 per cent sheep and 21 per cent camels. Horses and donkeys were owned by less than one per cent of the households. Individual rather than joint livestock ownership pattern had been in vogue. The kind and amount of livestock owned varied from tract to tract.

Table 8(A) : Tract-wise percent of households owning livestock

Livestock Type	% households in tracts		
	Pastoral	Rainfed	Irrigated
Milch cows	63	71	78
Non-milch cows	24	11	-
She buffaloes	17	29	40
He buffaloes	3	3	80
Bullocks	38	28	54
Goats	68	62	39
Sheep	37	24	18
Camels	32	24	2

Table 8(B) : Type-wise mean number of livestock per household in different tracts

Livestock type	Mean number of livestock per household Pastoral	Rainfed	Irrigated	Total
Cattle	10	4	6	7
Buffaloes	Neg.	1	1	1
Sheep	50	18	9	25
Goats	10	10	6	9
Camels	1	1	Neg.	1
Others	1	Neg.	Neg.	Neg.
Total	72	34	22	43

On an average a herd of livestock owned 43 animals out of which sheep constituted 25, Goats 9, Cattle 7, Buffalow 1, and Camel 1. Variations in type of livestock in a herd of different tract are revealed in the above table.

Comparative data of the tracts have revealed that with the decrease in aridity i.e. from pastoral tract to rainfed dry farming to salinity affected irrigated tract, the households owning cows have increased from 63% to 71% to 78%; Buffaloes from 17% to 29% to 40%. Among draught animals bullocks increased from 32% to 24% to 2% in the three tracts. Whereas household owning sheep and goats decreased considerably from 37% and 68% to 24% and 62%; to 18% and 39% respectively. Thus with the increase in aridity, the tendency of keeping increasing number of sheep, goats and camels has increased in the tracts. Increase in number of households owning livestock further strengthens desertic conditions in the area.

H. Animal husbandry practices

Irrespective of the tract animal husbandry practices followed are chiefly traditional with regard to breeding, castration, treatment of ailing animals, feeding, marketing, etc. More than three-fourths of the respondents of all the tracts reported various physical and socio-economic constraints in adopting improved animal husbandary practices. Frequent droughts, shortage of grazing lands and water scarcity traditional attitudes, beliefs in Gods goddesses associated with livestock diseases and mortality, belief of customary rituals for the ailing livestock, inheritance law of property distribution and lack of capital were believed to be the major causes of non-adoption of improved practices.

It is recommended that the traditional animal husbandry practices may be substituted with the scientific ones for higher productivity and better quality of livestock.

Increase in livestock population, less growth of grasses, cultivation of grazing lands and growth of useless vegetation all in association with the traditional style of grazing and management of herds have resulted in bringing changes in the quality of grazing lands in the area. On the basis of experience the villagers reported that during the last 30 years the quality of grazing lands have been more deteriorated in the irrigated tract as compared to pastoral and rainfed tract.

I. Livestock migration

Unhala (summer) and Chomasa (rainy season) type of livestock migration for a short period of less than one month and of long period of more than one month was chiefly prevalent in the pastoral, rainfed and irrigated tracts. During the last drought year, more than one-fifths of the households migrated alongwith their livestock. The routes of migration differed according to the type of livestock; sheep and goats migrated towards Jaipur and Haryana while cattle migrated towards Kota. Routes were determined on the basis of grass/fodder, water and availability of agricultural labour. Decision of migration routes to be followed was chiefly taken collecctively reported by 48% of the households in all the tracts. There were 31 different routes of livestock migration to be followed by the livestock raisers of all the tracts. Of the various reasons of sending livestock for long distances, shortage of fodder followed by drought/famine occurrences, fear of death, water and fodder difficulty and shortage of food grains were the most predominant reasons in all the tracts.

Each type of migratory household associated with some kind of livestock make indiscriminate use of meagre available water and grazing resources in the tracts. These in the present day thus prove a menace for the whole society and their sedentarization is inescapable. The rehabilitation schemes formulated on the basis of their kinship structure and cultural values are likely to yield fruitful results.

J. The role of livestock in desertification

High growth rate of livestock resulting in increased number has been depleting the Rajasthan desert of its phytomass resources resulting in ecological imbalance (Kalla, et al, 1977). A view also holds that most of the world's deteriorated rangelands have been caused by over-grazing by cattle and sheep. But two conflicting views prevail as to the goat's role in land use: (i) the goat is the major cause of deforestation, rangeland destruction and soil erosion, and as such, its propagation should be checked, and (ii) this animal is of considerable value as the "poor man's cow" (some even call it the "Walking Refrigerator") and as the major supplier of animal protein in our diet and, as such should be included in a rational grazing programme.

The importance of goats, lies not merely in the returns this hardy animal gives to the owner but also in its role in raising of sheep. Goats often acts as foster mothers to lambs as well as assist the shepherd in grazing and herding the sheep. Also, in case of any attack by wild beasts it is only the goat which bleat and given an instant indication to the owner about the attack. The rate of mortality among sheep is comparatively much higher than in goats during scarcity conditions. It is common saying that *"oont chhodde aakra aur bakri chhodde kankra"*. *i.e.* during scarcity conditions, the camel will only leave the *Calotropis* but the goats will leave only pebbles. This implies that the goat can survive on the most scanty vegetation. If, therefore, the goat is to be displaced because of its alleged association with rapid range denudation and soil erosion, a suitable substitute has to be found in order that there may not be a functional vacuum with consequent (difficulties in sheep rearing which is an important arid zone industry

Blaming the goat for the vast destruction of the world's pasture and forest resources may, therefore, be unrealistic. however, in India the National Commission on Agriculture has come down rather heavily on the goat and has recommended drastic reduction in its number in the desert areas.

When grazing or browsing cut over forest areas, goats prevent tree regeneration by consuming the young shoots, but cattle and sheep also cause appreciable damage of the same nature in similar circumstances. Goats are also accused of damaging crops; but, in actual fact, the natural grazers, i.e. cattle and sheep, can often be even more destructive. With both forest and crop damage, the type of stock is usually a less important factor than the number of livestock, irrespective of species. It is a widespread lack of control and the careless management of the animals which are chiefly responsible for the destruction incurred.

What is needed, then, is to maintain a balance between the total number of goats (and other livestock) and the quantity of feed which is available for the combined population during the lean periods.

In other words, the carrying capacity of the land has to be determined and respected. There is no sense in discriminating unjustly or unnecessarily against one particular species, the goat. In extreme situations where elimination of the goat from the eco-system is considered logical the probable effects of its disappearence on the existing vegetation and on the low level of animal production in the region should be carefully considered. It will be well to remember that where feed is scarce and of low nutritive value the larger animals are at disadvantage because of their greater maintenance requirements. Smaller animals like goats with correspondingly lower maintenance needs, are often able to roam over larger areas to gather sufficient nutrients for both survival and at least the minimal production of meat and milk (Ghosh and Khan, 1980).

The goat has a strong justification to continue to exist as part of our agricultural practices, at least in such areas where the potential for sedentary agriculture is at best minimal. The controversy that has been ragging concerning the goat does not originate in the goat *per se* but in the uncontrolled and continued overgrazing by this agile and inquisitive animal. The approach to contain the menace so far fallaciously believed to be posed by the goat should be to upgrade it and control its movements, rather than doing away with it (Ghosh and Khan, 1980).

However, cumulative effect of constant increase in number of people and animals is serving damage to the limited natural resources of the arid lands. The complex man-land-livestock interactions inherent in resources use and abuse have revealed in degradation of arid land, depletion of water resources, destruction of rangeland vegetation and deforestation. Pastoralists opined that vast areas earlier covered with thick forests bush/grassland . sustaining balance of livestock have deteriorated to eroded waste of bare sandy soils. The rainfed and irrigated pockets of the area have been infested by uselessunpalatable shrubs.

IV. SUMMARY AND CONCLUSION

Animal-human interactions, inter relations, conditions and consequences form the components of desertification processes in the arid areas. Animal human activity in the Indian desert, has revealed that ecological deterioration and accentuation of desertification has been occuring in the region in recent times due to the intense human and livestock pressure. The increased pressure of livestock on the natural grazing lands resulted in over exploitation of resources leading to depletion of natural vegetation. Livestock population trend, growth, composition, type and density were found to be the chief livestock parameters influencing desertification process in different ecological regions of arid zone of Rajasthan.

Livestock population exceeds human population. Despite climatic vageries, there is an increase in livestock population. Growth of livestock population is higher in the pastoral tract as compared to the rainfed and irrigated tracts within the arid zone of Rajasthan. Despite ecological differentiation, growth of sheep and goats together is highest of all the animals. There is an increasing tendency of keeping large number of animals among the pastoralists. Households owning cows and buffaloes increase with the decrease in aridity from the pastoral to rainfed to irrigated tracts. Households owning sheep and goats increase with the increase in aridity and decrease with the decrease in aridity. Rearing of sheep, goats and cattle is no longer a monopoly of the traditional livestock rearing communities of arid zone of Rajasthan.

In arid zone of Rajasthan livestock had increased from 9.90 million in 1951 to 23.32 million in 1983 with a net increase of 135.56%. Amongst various ecological regions, pastoral tract revealed an alarming situation for the planners as it had the highest livestock growth of 263.26% during 1961-'83. In the rainfed tract livestock population had increased by 121% during the period of 1961-'83. While in the irrigated tract livestock had increased by about 28% during the period of 1956-83. Livestock population varied from minimum 1.68 per capita in the irrigated tract to maximum 8.86 in the pastoral tract. Highest mean annual growth rate of 11.97% was found in the pastoral tract as compared to 5.45% in the rainfed tract during the period of 1961-83 and 1.06% in the irrigated tract during 1956-83. Highest growth rate of cattle (82%) and sheep (64%) took place in the pastoral tract during 1977-83. Sheep and goats together constituted more than four-fifths of total livestock in the pastoral and irrigated tracts as compared to 59% only in the irrigated tract during 1983.

With the increase in aridity from irrigated tract and dry farming to pastoral, the households owning sheep, goats and camels have increased. Inspite of frequent droughts and famines, there is also an increasing tendency among the pastoralists to keep large number of animals. This along with traditional attitude and beliefs in Gods/Goddesses associated with livestock diseases and mortality, customary rituals for the ailing livestock, inherited law of property distribution and lack of capital are believed to be the major socio-economic constraints in adoption of improved animal husbandry practices.

Increase in livestock has over crowded the permanent pastures and other grazing lands. Density of adult livestock units/100 ha of pastures and grazing lands was found to be 708 in the pastoral tract, 1362 in the dry farming, and 570 in the irrigated tract. A positive degree of association persists between the livestock population increase and in the intensity of depletion of grazing lands in the tracts. Fast increase in livestock population inspite of gradual shrinkage in the extent of grazing lands has resulted in over-exploitation of grazing lands and also to partial starvation of livestock. More than three-fourths of the households in all the tracts reported that the present grazing grounds were inadequate and getting deteriorated. Consequences of too many livestock using grazing grounds were stated to be partial starving of livestock due to shortage of grasses, land getting spoiled and becoming weaker, and soil erosion due to trampling of livestock.

As an adjustment mechanism Unhala (summer) and Chomasa (rainy season) type of livestock migration for a short period of less than one months and of long period of more than one month was chiefly prevalent in the pastoral, rainfed and irrigated tracts. During the last drought year more than one-third of the households migrated alongwith their livestock. Each type of migratory household associated with some kind of livestock make indiscriminate use of the meagre available water and grazing resources of the areas.

Consequently the huge pressure of livestock population, majority of sheep and goats, increasing tendency of keeping larger number of animals, traditional management practices, over crowded permanent pastures, deterioration of grazing lands and difficulties in migration - all have become conducive to desertification in the area.

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12

LIVESTOCK FARMING - A FORM OF LAND USE IN W. RAJASTHAN

Amal Kumar Sen

I. INTRODUCTION

Rajasthan ranked third and contributes about 12 percent of the total livestock wealth of India. The source of livestock and animal husbandry in the state income of Rajasthan at current prices, in the 1976-77 stood at 16.71 percent and 15.64 percent at constant (1969-61) prices. Agro-climatic structure of W. Rajasthan or the arid zone of Rajasthan renders livestock and animal husbandry specially significant in the cast of landuse of Arid Zone of Rajasthan. In the arid zone climate is dry, the physiography is characterised either by sandy or rocky desert, dune and interdune sandy terrains, saline flat and depressions or playas (locally known as rann) sparsely populated and single cropped land. In this region therefore, animal husbandry is not merely an adjunct to agricultural operational but supplementary avocation for the peasantry. In short, livestock farming has traditionally been one of the most viable elements of the agro-economic system of the arid zone of Rajasthan, Recognising the importance of range management and livestock farming, considering the constraints imposed by aridity, to upgrade the economy of the state, livestock farming has already been suggested, as one of the most important alternate land use for arid zone of Rajasthan. The National Commission on Agriculture has in its report on developmental strategies for the desert areas, laid strong emphasis on the need for strengthening the livestock farming sector, (Sen, Ghosh et al., 1981). Besides livestock plays a vital role in the economy of the arid zone of Rajasthan - source of manure and fuel, bones, horns, hoops, milk, hides, skins etc., Cattle, Camel and other livestocks also serve as draught power for agricultural operations, such as thrashing and lift irrigation in the rùral areas. Milk cattle is a source of milk supply to other regions. Meat and poultry products are also supplied and exported to the other parts of the country. All these emphasises the importance of livestock farming and hence pasturing as a landuse unit in the arid zone of Rajasthan.

II. THE BASIC NEED - LANDUSE IN INTEGRATED SURVEY

The consideration of any form of landuse in W. Rajasthan should be proceeded by an accurate assessment of the resources in dry land eco-system-their extent and distribution so that these could be harvested efficiently for productive exploitation towards total human welfare. This necessiates multidisciplinary integrated surveys of natural resources. The end product of integrated surveys is the generation of a proposed land utilization map which provide a clear picture of lands where livestock farming or pasturing can be undertaken (Shankarnarayan, 1984).

III PRESENT LANDUSE OF WESTERN RAJASTHAN

Table 1 gives the present landuse in the districts of arid western Rajasthan for the period 1976-77 to 1980-81. The figures are collected from the revenue department of Govt. of Rajasthan. The average figures of the four years are taken into account. The table indicates the highest % of land is under single crop. The permanent pasture or

Table 1. Present Landuse in arid Rajasthan (1976-77 to 1980-81)

	area in hectare	Percentage
Forest	285683	1.72
Settlement and water features	685659	3.29
Rocky waste & stony waste	987579	4.74
Sandy waste (cultivable waste)	5129338	24.63
Permanent pasture oran	846894	4.06
Orchards and plantations	28270	0.13
Cultivated lands		
Single cropped	9072278	43.68
Double cropped	805449	3.86
Long fallow	1542910	7.41
Short fallow	1393150	6.69
	20777210	100

Grazing ground : 8506721 ha or 40.84%

Cult. lands 12813787 ha or 61.64%
(including long fallow which is also grazing land.)

Oran constitues only 4.06%. But this is not the only unit that forms pasture grounds. Rocky and stony wastes, sandy wastes and long fallows also constitute grazing grounds. Thus the grazing ground available is about 41% - although about 7% of it (long fallow) are occassionally cultivated in long duration (4 to 5 years) - only in the years of very favourable rainfall. This secondary data only present the qualitative picture and don't show the extent of the pasture grounds. Even so it shows that the available grazing ground is sizeable. In view of this situation it appears that animal husbandry may be the most appropriate enterprise in this region. Therefore, the lands, which can not sustain cultivation must be adequately safeguarded by prescribing appropriate landuse and needed practices.

IV LANDUSE CLASSIFICATIONS OF GRAZING GROUND IN DESERT ECO-SYSTEM

The degree and extent of landuse units can be best cartographed by means of field survey and remote sensing devises. Based on the intensity of survey topographical maps - aerial photographs and landsat imagery interpretations, collection of field data and available informations, etc. three types of the landuse maps can be prepared from the restriting details viz., reconnaissance, detail reconnaissance and detail landuse maps. These are large sale maps being 1 : 100,000 to 1 : 50,000 1 : 25,000 and 1 : 15,000 or more in general in case of reconnaissance, detail reconnaissance or detail maps respectively. These maps show the extent and degree of landuse classes and thus depicit the actual pattern of landuse. These are helpful to delineate or find out problem areas, planning and execution works (Sen, 1981).

Based on such survey and remote sensing devices the area under present landuse units are presented in maps 1 to 5. The present landuse and its relation to agricultural and livestock farming aspects can be best studied or geographically analysed by classifying the area into agro-climatic and agro-ecological regions. The arid zone of Rajasthan has earlier been classified into two macro and four micro agro-ecological regions (Table 2) (Sen 1972 'a'and 'b'). The land use characteristics of these zones are also shown in Table 2

Table 2. Agro-ecological and agro-climatic regions of Western Rajasthan.

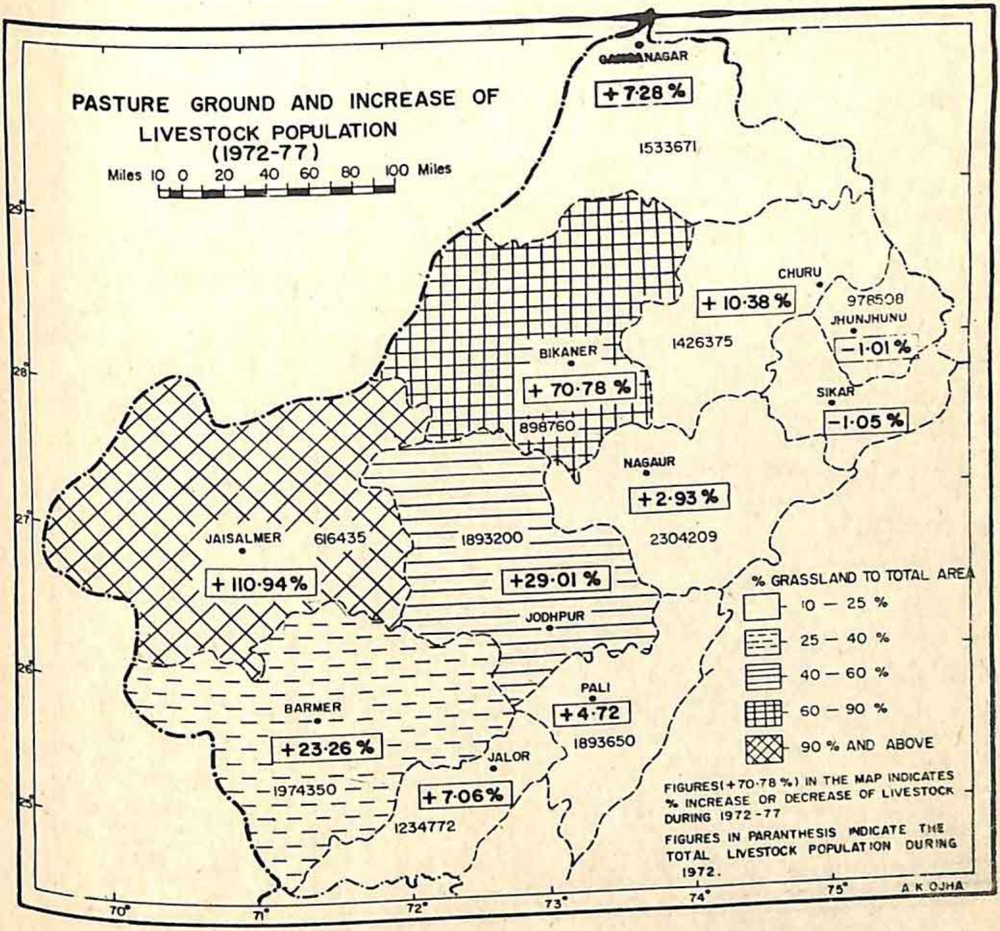
Macro Region	Micro region	Districts included	Area in Km^2 and %
1. Arid	1 a Kharif Mono-cropping.	Barmer, Jodhpur Churu, Jaisalmer, & Bikaner.	133,722 (64.20%)
	1 b Irrigated Kharif and Rabi cropping	Ganganagar	20,764 (10%)
2. Transitional hetric and arid and semi-arid	2. a Kharif Mono-cropping.	Jhunjhunu Sikar, and Nagaur.	31,244 (15%)
	2. b Irrigated Kharif and Rabi cropping	Pali and Jalore	82,780 (10.80%)

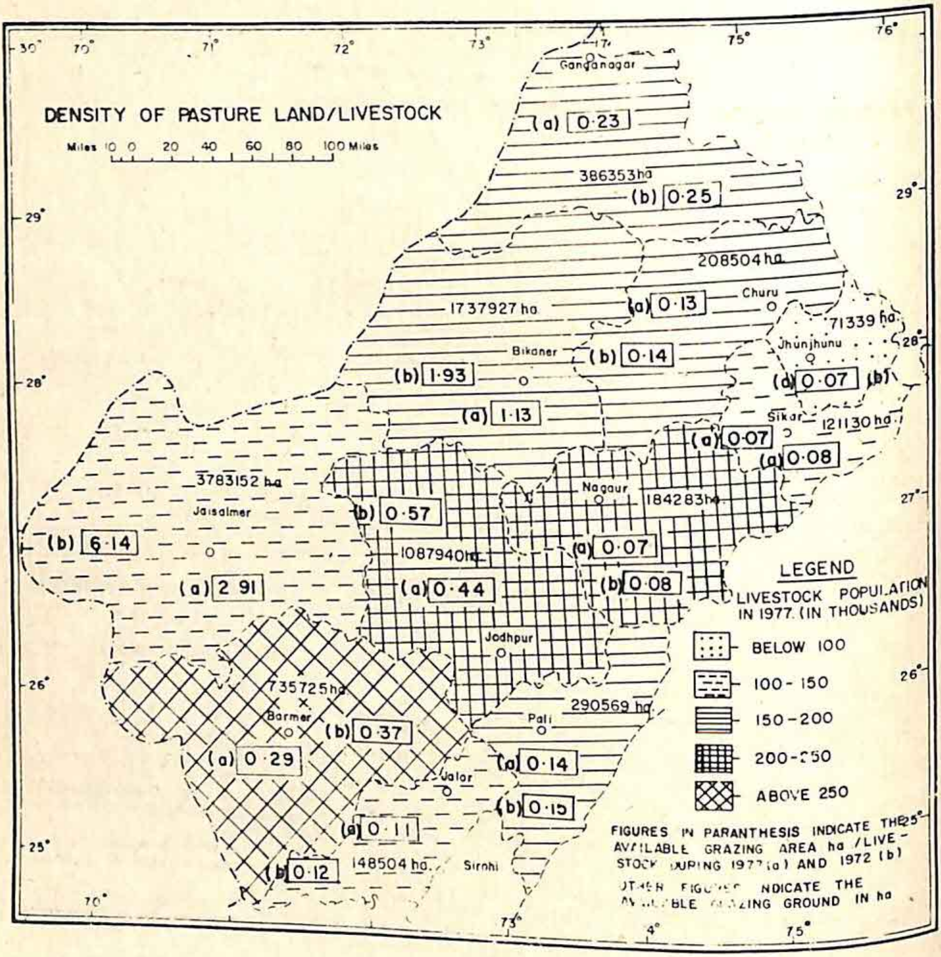
Table 3 indicates that parmanent pasture or Oran land (II) waste lands including ten sub-classes, (v) primarily constitute the grazing ground. Besides the marginal lands where intensity of cultivated lands are less than 20% also comes under grazing ground during the drought years. Thus the actual pasture lands which form 46 percent of the total area of western Rajasthan includes Oran, wastelands and marginal lands.

The availability of grazing ground in W. Rajasthan is quite high in comparison to national figure. In W. Rajasthan about 42%, is available for grazing. The figure is above 50% in arid zone, while in Arid Kharif mono cropping belt more than 55% of the total area is available for livestock farming. In Jaisalmer the available grazing ground exceeds

Table 3. Pasture grounds in W. Rajasthan.

Districts	Total area in hectare	Pasture lands in ha & %			Total
		Permanent pasture Oran	Waste lands	Marginal lands	
1A. Jodhpur	2217800	133500	682790	271650	1087940
		(6.02)	(30.79)	(12.25)	(49.06)
Bikaner	2885072	26597	1417020	294380	1737997
		(0.92)	(49.12)	(10.20)	(60.24)
Barmer	2817294	214466	501974	19285	735725
		(7.61)	(17.82)	(0.7)	(26.13)
Jaisalmer	4135700	145408	3634723	3021	3783152
		(13.42)	(87.88)	(0.08)	(91.48)
Churu	1685114	49261	57100	102143	208504
		(2.92)	(3.39)	(6.1)	(12.37)
Total Arid Monocropping	13740980	569232	6293608	690479	7553319
		(4.14)	(45.90)	(5.02)	(55.06)
1b. Ganganagar	2041446	25910	301451	38792	386353
		(1.27)	(14.77)	(3.0)	(19.04)
Total arid	15782426	595142	6595059	6729171	7919672
		(3.77)	(41.78)	(4.62)	(50.18)
2a. Sikar	774925	48200	71044	1889	121130
		(6.22)	(9.17)	(0.24)	(15.63)
Jhunjhunu	592730	44589	24924	1826	71339
		(7.53)	(4.20)	(0.30)	(12.03)
Nagaurr	1768011	80400	84600	19283	184283
		(4.55)	(4.78)	(1.1)	(10.43)
Total Transitional Monocropping	3135666	173189	180565	143602	497356
		(5.53)	(5.76)	(4.60)	(15.86)
2b Jalore	1056357	51139	96709	956	148504
		(4.84)	(9.15)	(0.06)	(14.05)
Pali	1229762	92463	178144	19962	290569
		(7.52)	(14.49)	(1.62)	(23.63)
Total Transition Kharif & Rabi Cropping	228619	143602	274853	20618	439073
		(6.28)	(12.02)	(0.90)	(12.20)
Total Transitional Arid & Semi-Arid	5421785	316791	455418	164220	936429
		(5.84)	(8.40)	(3.03)	(17.2)
Total W. Rajasthan	21204211	911933	7050477	893691	8856101
		(4.30)	(33.25)	(4.21)	(41.76)

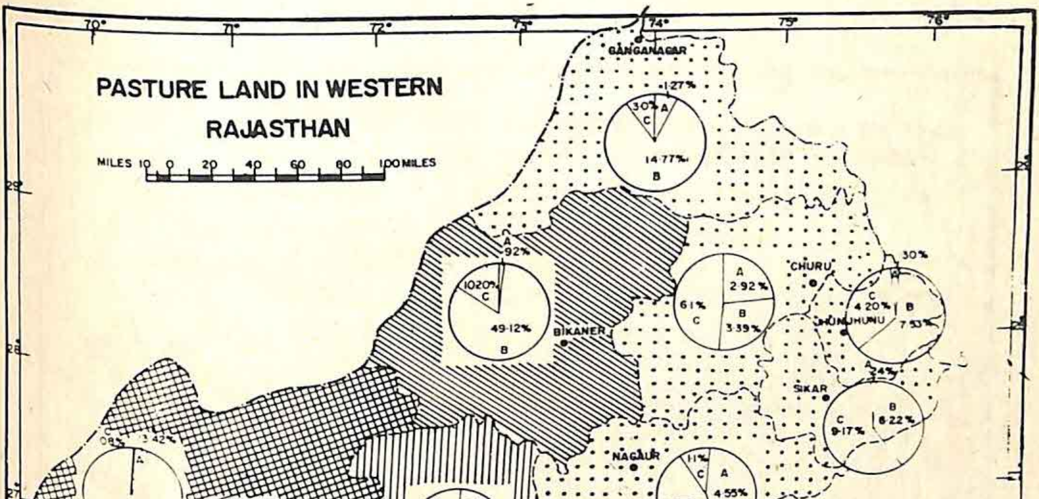

PASTURE GROUND AND INCREASE OF LIVESTOCK POPULATION (1972-77)
Miles 10 0 20 40 60 80 100 Miles
GANGANAGAR
+7·28 %
1533671
CHURU
+10·38 %
1426375
978508
JHUNJHUNU
-1·01 %
SIKAR
-1·05 %
BIKANER
+70·78 %
898760
NAGAUR
+2·93 %
2304209
JAISALMER
616435
+110·94 %
1893200
+29·01 %
JODHPUR
PALI
+4·72
1893650
BARMER
+23·26 %
1974350
JALOR
+7·06 %
1234772
% GRASSLAND TO TOTAL AREA
10 — 25 %
25 — 40 %
40 — 60 %
60 — 90 %
90 % AND ABOVE
FIGURES(+70·78 %) IN THE MAP INDICATES % INCREASE OR DECREASE OF LIVESTOCK DURING 1972-77
FIGURES IN PARANTHESIS INDICATE THE TOTAL LIVESTOCK POPULATION DURING 1972.
29°
28°
27°
26°
25°
70°
71°
72°
73°
74°
75°
A K OJHA

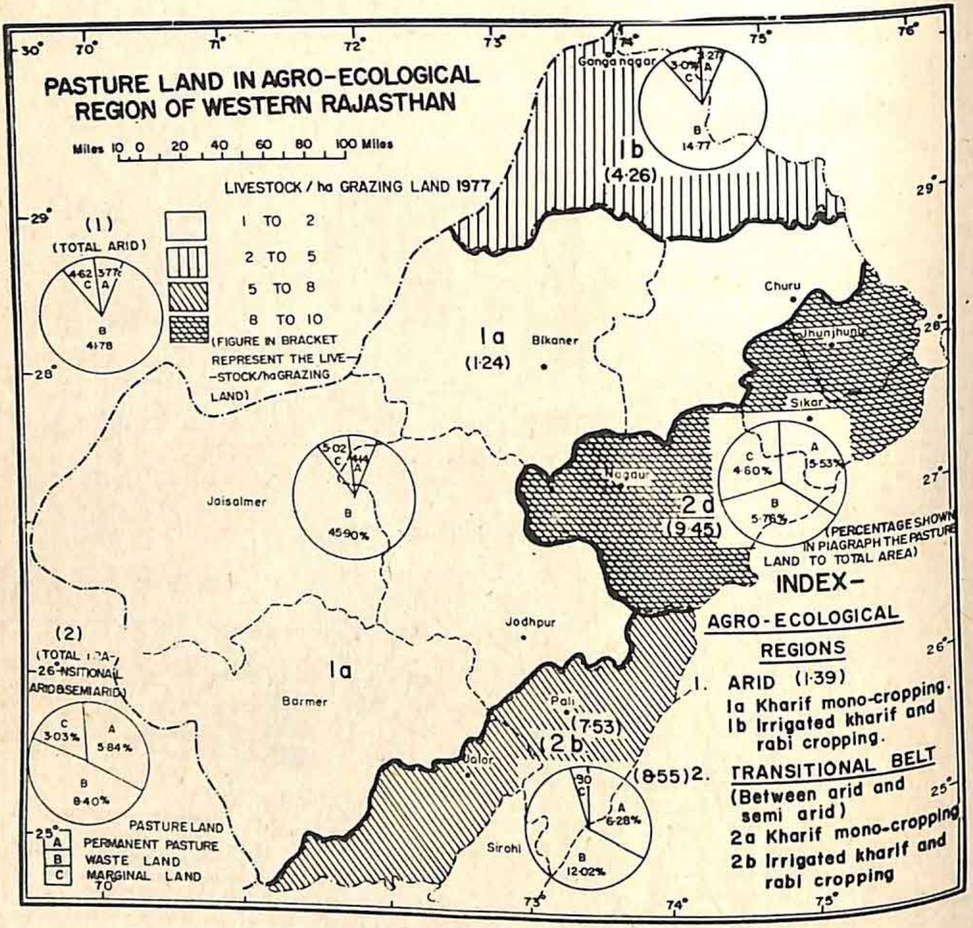


DENSITY OF PASTURE LAND/LIVESTOCK

FIGURES IN PARANTHESIS INDICATE THE AVAILABLE GRAZING AREA ha /LIVESTOCK DURING 1977 (a) AND 1972 (b)

OTHER FIGURES INDICATE THE AVAILABLE GRAZING GROUND IN ha


PASTURE LAND IN WESTERN RAJASTHAN
MILES 10 0 20 40 60 80 100 MILES
GANGANAGAR
BIKANER
CHURU
JHUNJHUNU
SIKAR
NAGAUR
JAISALMER
JODHPUR
BARMER
PALI
JALOR
INDEX÷
PERCENTAGE OF TOTAL PASTURE LAND TO TOTAL AREA
BELOW 20%
20 TO 50%
50 TO 80%
80% AND ABOVE
W. RAJASTHAN
PASTURE LAND
A PERMANENT PASTURE, ORAN LAND
B WASTE LAND
C MARGINAL LAND
(PERCENTAGE IN PIAGRAPH REPRESENT THE PASTURE LAND TO TOTAL AREA)
70° 71° 72° 73° 74° 75° 76°
29 28 27 26 25



PASTURE LAND IN AGRO-ECOLOGICAL REGION OF WESTERN RAJASTHAN

90%, while in Bikaner it is above 60%. The low figure in Barmer and Churu is however due to the increased use of marginal lands for cultivation which however, is a menace to desertification and soil erosion. Same is the case with the districts of Nagaur. Sikar and Jhunjhunu. In Pali and Jodhpur districts saline waste accounts for the availability of more grazing ground.

V INTERPRETATION OF AERIAL PHOTOGRAPH AND LANDSAT IMAGERY TO DELINEATE RANGE LANDS

The informations generated through "edge gradient" study of the aerial photograph and land sat imagery - like vegetative areas, topographic and cultural features which affect the suitability of range for livestock etc. can be transferred to maps or compiled in tables and charts to guide the range management specialist to covey out his plans (Jogy Harus and Raduer, 1960).
ADVANTAGES : i) Improve the reliability of range inventories, ii) Boundaries of types and sub-types can be delineated quickly and accurately as fall on minute ground features readily discrned on photographs but not on ground. iii) Range improvements like fences saline areas, watering places can be accurately located, iv) Facilitate selection of sample plots of large range areas where vegetation types are irregular in shape. Distance and direction from the land mark to the sample location can be determined by photographic measurement.

Generation of data and delineation of boundaries of range land is possible in large remote and under developed regions like desert in much shorter time than any other methods. One of the advantage of the landsat is that the whole area is photographed at the same time and under identical lighting conditions.

VI PRESSURE OF LIVESTOCK POPULATION ON GRAZING GROUND : A PROBLEM OF LIVESTOCK FARMING

Table 4 indicates that the livestock population
and that pressure on the grazing land in Rajasthan
in considerably high. The result has been overgra-
zing and deterioration of the surface vegetation-
conditions largely responsible for increased deser-
tification hazards. The table gives an account on
the variation and increase of livestock population
during the period 1972 to 1977 in different districts
of arid zone and their pressure on grazing land
in different agro-climatic regions of Rajasthan.
It is evident not only the livestock population has
increased unit the pressure on grazing has already
led to an over-grazing. In Western Rajasthan in
view of their low carrying capacity, the increased
pressure of livestock on the national grazing lands
results in over-exploitation of resources leading
to depletion of consequences on settlements, commer-
cial and other infrastructure. In view of this context
the need for rational utilization of available resources
in the rangelands becomes evident. It emphasis
the needs of organising livestock farming - as a
form of alternate land use in arid Rajasthan.

VII LIVESTOCK FARMING-PASTORAL LAND USE MANAGEMENTS

Land use survey data indicates that more
than 41% of W. Rajasthan is used as grazing ground
a form of pastoral landuse. Besides there is a
scope to develop livestock farming also in the single
cropped or mono-cropping lands. What is needed
as observed by Shankarnarayan (1984) a systematic
screening to exploit the full genetic potential of
the native grasses for realising increased animal
production. The improved strains of grasses identified
and developed thus represent non-cash inputs in
demand and supply position. To make livestock far-
ming more lucrative, intensive research is needed

Table 4. Livestock population grazing area/livestock in ha.
Pressure of livestock population on grazing land.

District	Total grazing ground in ha.	Livestock population			
		1972 (total)	grazing land/ livestock	1977	grazing land/ livestock
1. Bikaner	1737927	898760	1.93	1534983 (+70.78)	1.13
2. Barmer	735725	1974350	0.37	2534983 (+28.26)	0.29
3. Churu	208504	1426375	0.14	1574522 (+10.38)	0.13
4. Jodhpur	1087940	1893200	0.57	2442424 (+29.018)	0.44
5. Jaisalmer	3783152	616435	6.14	1300419 (110.85)	2.91
6. Ganganagar	386353	1533671	0.25	1645431 (+7.287)	0.23
7. Sikar	121130	1530178	0.08	1361092 (-1.05%)	0.08
8. Jhunjhunu	71339	970508	0.07	968588 (-1.01%)	0.07
9. Nagaur	184283	2304209	0.08	2371741 (+2.93%)	0.07
10. Jalore	148504	1234772	0.12	1322045 (+7.06%)	0.11
11. Pali	290569	1893650	6.15	1983093 (+4.72)	0.14
Total	8856101	14584108	0.61	19036651 (+3.03)	0.46

for increasing the genetic potential of the grasses through multi-disciplinary efforts for such attributed as quality, high dry matter yield, vigour and regeneration ability which are to be incorporated in the genotypes. Studies on forage preservation like hay making, and storage in good to very good rainfall years for use in drought periods needs examination in relation to livestock needs and thus prevent migration of livestock.

VIII. SILVIPASTORAL MANAGEMENT

Since livestock husbandry occupies the most important place in the economy of the arid region and that frequent droughts result in loss of livestock owing to the shortage of fodder resources, it is necessary that range improvement programme is also complemented by raising fodder trees and shrub species (Paroda, Mann & Verma, 1980). Introduction of suitable tree species will not only provide nutritionally better quality fodder during the ban period but will also be useful in nitrogen build up in the soil and source as shade tree for grazing animals. In addition fodder trees and shrubs will ameliorate the microclimatic conditions and thereby improve conditions for better regeneration of grasses.

IX CONCLUSIONS

Due to the constraints imposed by aridity agriculture is often given a low priority for the development of arid lands. Range management and dairy farming has been favoured to give top priority in arid land. Accordingly livestock farming has been suggested as an alternate land use of Western Rajasthan.. But the present management system needs improvements: Over-grazing and over exploitation of the range land resources have already caused environmental degradation in arid eco-system which need considerations. An integrated basic resources survey, with the help of aerial photo interpretation and remote sensing techniques is needed to map the range lands and to pinpoint the associated problem areas to work out land treatment programmes in detail.

Acknowledgement

Grateful thanks are due to Dr. K.A. Shankarnarayan, Director, and Dr. P.K. Ghosh, Senior Scientist S-4 of CAZRI, for their keen interests in the work.

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DESERTIFICATION IN INDIA : EXTENT, CAUSES AND CONTROL

J.K. Jain

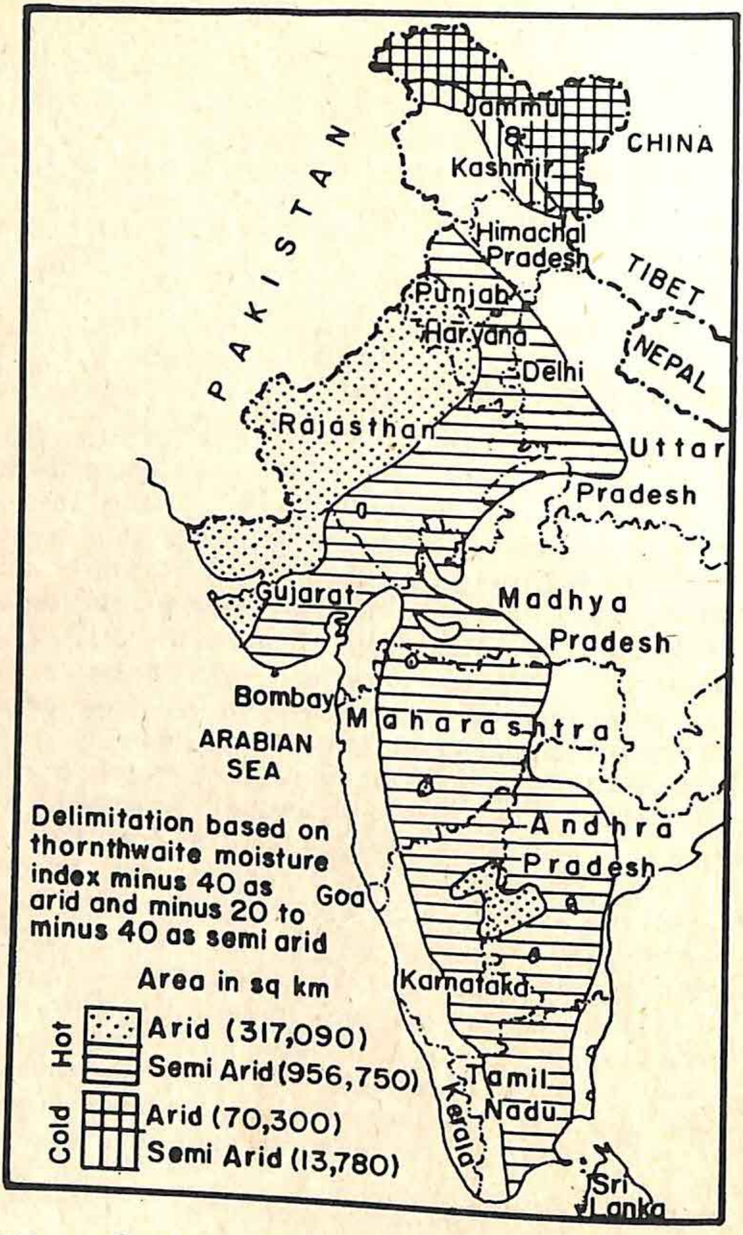
I. EXTENT OF DESERTIFICATION

The arid zone in India constitutes a significant portion (about 12 per cent) of the geographical area of the country. It extends over a wide latitude covering both peninsular and extrapeninsular regions (Fig. 1). The northern portion of the arid zone is the continuation of the major Afro-Asian hot desert region. Biogeographically, the biota of this tract holds 'western' affinities to a great extent. The cold arid tracts located in the Himalayan zone depict entirely different biogeographical attributes.

Taking into account the manifestation of aridity in the natural setting and ecological features, the core regions of the arid tract of this country, including a small extremely arid area, are broadly restricted to Rajasthan and its neighbouring states of Gujarat, Punjab and Haryana. The focal centres for manifestation of desertification are most pronounced in the Rajasthan region, especially in view of the intrinsically 'desertic' nature of this zone. As such, the bulk of investigational and implementational activities of various agencies have been, to an extent, restricted to the Rajasthan state and its proximal areas.

The area and population of the arid states of India are shown in Table 1.

The arid regions of India are having a population of over 25 million with an average density of 74 persons per km^2, as against 4 persons per km^2 in most other deserts of the world. The density



Source : Central Arid Zone Research Institute, Jodhpur.

Note : The external boundary and the coastlines of India appearing on the map are neither verified nor authenticated by the Survey of India

Fig. 1. Schematic map of India showing arid and semi-arid zones

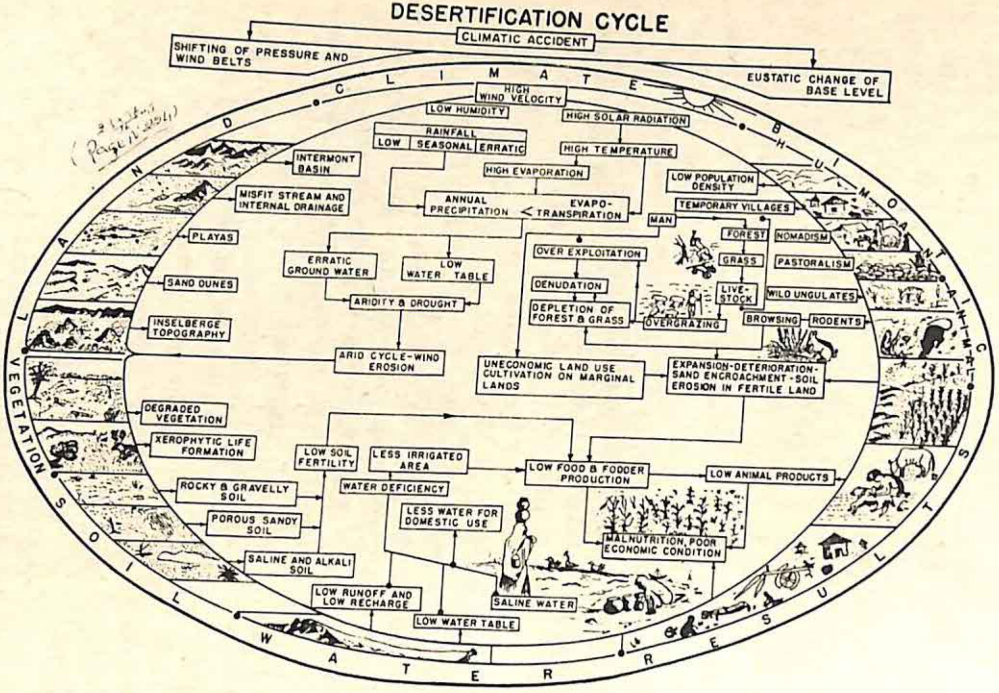
Table 1

Name of arid state	Area under arid zone ('000 km^2)	Population 1981 ('000)
Rajasthan	196.4	11,879
Gujarat	66.1	3,604
Punjab	14.8	3,463
Haryana	12.9	2,447
Andhra Pradesh	19.9	2,685
Karnataka	8.2	1,136
Maharashtra	1.3	268

of population gradually increases towards the east and northeast near the borders of Punjab and Uttar Pradesh. There is a broad correlation between aridity and sparseness of population, with exceptions in urban-industrial clusters like Jodhpur and Bikaner. The distribution and density of population can be expressed in terms of availability and suitability of surface and groundwater. Population density increases where the rainfall increases or the water table approaches the surface. The highest population occurs in the piedmont belt of the Aravallis all along its western borders and the narrow zone between the Sutlej and the dry bed of the Ghaggar in the extreme north. The relationship between the distribution of population and availability of water is obvious in the arid and semi-arid lands. However, variations in the densities of population do occur on account of differences of topography, soil, land, occurrence of economic minerals, accessibility and other socio-economic factors.

II CAUSES OF DESERTIFICATION

The causative natural factors of aridity and desertification are the inherent climatic conditions and geological and geomorphological setting (Fig.2). The rocks are submitted to extreme temperature variations, with resultant fragmentation and accumulation of detrital sands which are easily transported



Source : Mann, H.S. and Sen, A.K. (drawing by Tak,B.), Central Arid Zone Research Institute, Jodhpur

Fig. 2. Desertification cycle

by raging winds. High evaporation and low precipitation combine to create conditions which facilitate salinisation of the entire tract and accumulation of minerals in the surface and groundwater. Soil development is relatively poor due to the generally low organic detritus obtainable in the tract.

a. Deficient Rainfall

Analysis of precipitation records for more than seventy years reveals that the occurrences of large deficit years are frequent in the drier parts of the arid zone with values exceeding 20 per cent. Five-year moving averages for the period 1891-1975 show that the large deficit rainfall spell during 1962-71 (commencing in fact from 1956) is only comparable with conditions during 1895-1905. The 1901-60 period recorded only 3-4 spells of below-normal rainfall conditions of small magnitude.

Incidence of drought years has a multiplier effect on desertification. The conditions during the 1962-71 drought phase may have significantly contributed to the deterioration of the arid zone.

b. Duststorms Activity

The frequency of duststorms rises with reduced precipitation in the preceding years. Measurements of dust during 1973-75, from land surface to 3 m above, recorded 0.5 to 4.2 quintals per ha on a duststorm day at Jodhpur and 5.1 quintals at Jaisalmer. The removal of grass cover from 2,007 km^2 caused the depletion of 1,065 m^3 of soil in three years - a loss of 0.53 m of soil depth.

Observations indicate that the size fractions of the dust samples include fine sand (55-75 per cent), clay (6-15 per cent) and silt (14-39 per cent) under various landuse conditions and at various heights from land surface to 3 m above. The significant portion of silt in these samples indicates movement of fertile eroded soil over large distances. In fact, dust rises to more than 5,000 m over the arid zone - the cause for the midtropospheric divergence that reduces rainfall in the area despite the presence of moisture.

c. Shift of Aridity

The variation of the aridity index line of 80, computed by Penman's method and studied for the period 1901-70, reveals an eastward shift during the first two decades of the twentieth century. Thereafter, there were minor to and fro oscillations, becoming more marked in Churu in the north and Jalore in the south, indicating maximum aridity eastward from 1951-60 in Churu and 1961-70 in Jalore. These studies imply a possible spread of arid conditions in the southeast.

d. Adverse Geohydrological and Geomorphological Conditions

1. Recurrent aridity in the geological history of the tract, with a particularly significant phase of wider extent in the early Quaternary, led to disorganisation of drainage in the Luni and Ghaggar basins and other northeastern zones (Kantli, Mendha etc) and creation of inland basins, salt lakes and a desert landscape of dunes, bornhardts and other associated features. As a result, considerable tracts outside the present limits of the arid zone in eastern Rajasthan are stabilised dune fields, with some pedogenesis. These zones are sensitive to irrational landuse practices, being well within the semi-arid belt.
2. Even after an interlude of ameliorating humid climate from 3000 to 1000 BC, during which the Rangmahal culture thrived in the Ghaggar, a second arid phase set in which is still continuing. Thus, the terrain did not have time enough to recover from the effects of the earlier phase of extensive aridity. This second phase of aridity once again led to further disorganisation of drainage, creation of an inland drainage

tract in the northeast, dune fields, sand sheets and erosional features like tafonis, bornhardts and rock pediments.

3. The Aravalli ranges effectively preclude the beneficial influence of the monsoons in the arid tract. These ranges have several windgaps and stream crossings which act as potential passages for wind transported material into the outer fringe areas in the direction of the prevailing winds.
4. In a terrain where evaporation is in excess of precipitation, the presence of inland basins and depressions with centripetal drainage and lack of a flushing system help in accumulation of saline material in the entire catchment area.
5. The geohydrological situation in the tract is one of restricted aquifers, often with brackish or saline water and deep water table. Recharge facilities are limited due to the low precipitation even in the fresh water aquifers (e.g. Lathi). This seriously hampers exploitation possibilities, recuperation of aquifers and maintenance of the groundwater regime.
6. Due to a combination of climatic and geomorphic factors there is hardly any surface water system with integrated drainage and appreciable discharge in this zone. The only exception is the Luni which, too, is a misfit and disorganised stream without any major sustained flow for most part of the year. The extensive salt Ranns of Kutch, into which the Luni discharges, also contribute to the salinity of the tract.

e. Pedogenic Limitations

Two major factors in the pedological character of the arid zone have significantly contributed to its desertification and lack of adequate vegetal growth These are:

1. Inadequate organic accumulation in the soils due to the prevalence of a climate unfavourable to vegetal growth, not only during the current arid phase but from the previous extensive phase of aridity. As a result, the soils even in the eastern tracts of the semi-arid zone manifest limited soil profile development, often on ancient stabilised dunes. The relatively richer soils are restricted to the fluvial margins and and flood plains; and
2. Well developed caliche formation (calcium carbonate material) in the soil profile, with considerable consolidation, inhibits normal root and vegetal growth in the region.

Apart from these basic pedogenic limitations, the intrinsic climatic conditions that promote erosion constantly remove the surface layers of the soil cover, resulting in impoverishment of plant growth environment. The movement of salinised water in some areas is also detrimental to soil productivity.

f. Population Pressure

Successive decennial census reports have revealed an alarming growth of human population in the arid regions of India from 3.6 million in 1901 to 13.4 million in 1981. There has also been a simultaneous rise in the number of livestock from 10.2 million in 1951 to 23.2 million in 1983, which is even greater than the human population. This has led to an adverse environmental situation, enumerated as follows:

1. Reduction of the man-land and livestock-land ratio in a tract which is normally devoid of adequate natural sustenance. The land per household has reduced from 17.8 ha in 1951 to 10.4 ha in 1981, with only 7.5 ha likely to be available at the turn of the century. There is a corresponding shrinkage in cultivated land;
2. Rise in net sown area from about 28 per cent in 1951 to 51 per cent in 1981, with double cropped area rising from 0.4 to 1.8 per cent. This has directly led to a shrinkage of lands normally used for grazing, with drastic removal of vegetal cover;
3. Overdependence on agriculture has led to land degradation due to nonavailability of adequate cultivated land; and
4. Urbanisation and industrialisation have further aggravated the man-land situation and reduction of forests for fuel and housing material.

9. Landuse Changes

Due to increased population and livestock pressure, vast areas of the arid zone have been brought under cultivation, often extending to marginal lands, pediment slopes of the Aravallis and other fringe areas, where the natural conditions do not warrant farming. These also include areas of stabilised dunes where farming and removal of roots and stubbles after cropping have led to accelerated wind erosion. Increase in livestock (partiularly goats and sheep) has resulted in further depletion of vegetal cover. Coupled with conversion of grazing lands to farming the region is undergoing an aggravation of desertification through erosion on bare lands and aeolian shifting of soil particles.

Introduction of irrigated agriculture in many areas, without adequate drainage measures, has also given rise to accumulation of minerals and salts in the soil and near-surface formations in a tract having naturally impeded drainage and heavily charged with minerals and salts. In some locations, there has been a rise of water table with simultaneous increase of salinity and deterioration of the soil regime. All these factors have led to diminishing returns from the land and enhancement of desertic conditions.

Establishment of new settlements (often on stabilised dune areas), urbanisation and construction of roads, railtracks and canals without regard to geomorphic units (stable dunes etc) have led to rapid mobilisation of stable sand belts and consequent desertification by removal of vegetal cover and wind action. As such, settlements and human constructions are the zones or centres of sand mobilisation and movement throughout the arid tract. This is rendered more acute by overgrazing and felling of trees for fuel.

Along the Luni riverine zone, there are several serious manifestations of regime deterioration in the form of salinisation of soil and water and development of negative gradients, particularly where dams have been constructed for storing and withdrawal of water. In many cases, withdrawal of water has led to lowering of water table below an optimum depth, with resultant desiccation and deflation. The Luni tract from Pichiak to Dhundara is a classical example of salinisation of fresh water and loss of land productivity. In the eastern fringe of the arid zone (Churu, Sikar and Jhunjhunu), there are evidences of widespread mobilisation of stable sand dunes as a result of human interference leading to the creation of source areas for materials which are easily transported across the arid zone boundary east-and-northeastwards into the Haryana-Punjab region through the windgaps in the Aravallis. In fact, comparison of the old toposheets with the new ones has indicated increase of sand in some of the semi-arid areas of eastern Rajasthan including Alwar, Jaipur and Tonk districts.

Geomorphological mapping in the eastern semi-arid fringe and along the Aravallis has indicated the presence of large sand deposits flanking both the windward and the leeward sides. Recent studies also reveal increase in some of these deposits near Sarwar and other locations east of the Aravallis. Observations along the windgaps (Pushkar, Tribeni and Sabi-Sote) show shifts in sands and new accumulations.

Although such windgaps are not extensive, they are nevertheless helping in the funneling out of desert sands into the regions beyond as a direct result of the deterioration of the conditions obtaining within the desert. Much of this outer zone is basically stable dune territory of the earlier arid phase where cultivation and human activities may lead to mobilisation and erosion. As has been experienced in other arid zones of the world, prolonged phases of drought may ultimately turn such sand accumulations in the fringe areas into menacing sources of loose materials that will cover the farmlands under greater desiccation and wind action.

The increased emphasis on the exploitation of minerals and rocks in the arid zone and its eastern fringe has led to extensive mining and quarrying, denudation of hill slopes and large scale loosening of rock faces - all leading to conditions that aggravate the processes of desertification.

As mentioned earlier, the increasing livestock pressure in the arid districts of Rajasthan and Gujarat has led to overgrazing, deforestation and exploitation of the woody biomoss in the region. This has resulted in extensive removal of vegetation with consequent erosion hazards. Rodents have also contributed towards desertification to an appreciable degree.

In conclusion, it may be stressed that the Indian arid zone is, even under normal conditions, an area with a relatively greater population density in comparison with other arid regions. The intense biotic activities have logically led to overexploitation of land and vegetation, triggering off a series of natural processes that are rapidly enhancing the physical manifestations of desertification.

III. CONTROL OF DESERTIFICATION

a. Institutional Infrastructure

The following institutions and government departments are engaged in research, surveys, investigations and pilot experiments on various aspects of arid zone problems in India:

1. The Central Arid Zone Research Institute (CAZRI) at Jodhpur is working under the Indian Council of Agricultural Research (ICAR), New Delhi. The institute has the following functional divisions - Basic Resources Survey Division (covering geology, geomorphology, hydrology, ecology, cartography and photo-interpretation); Plant Studies Division (covering range management, plant protection, horticulture, silviculture, toxicology and agrostology); Division of Animal Studies (covering animal ecology, rodent control, animal nutrition and physiology); Division of Soil-Water-Plant Relationships (covering agronnomy, plant physiology, water management, soil chemistry and soil physics); Division of Economics and Extension (covering sociology and agricultural economics); Division of Extension and Training (covering extension, training, information and audo-visual aids); and Division of Wind Power and Solar Energy (covering climatology, wind power and solar energy utilisation).

In addition, the institute, in collaboration with other agencies, is playing a leading role in various coordinated and operational research projects in the field of dryland agriculture, improvement of millets, water management and soil salinity, rodent control, drip and sprinkler irrigation and aridland management.

2. The Central Sheep and Wool Research Institute at Avikanagar is also working under the Indian Council of Agricultural Research, New Delhi. This institute is carrying out pilot studies, with demonstration units for extension work, on various aspects of improvement and promotion of livestock breeding, production of wool and management of grasslands. The Indian Grassland and Fodder Research Institute, Indian Veterinary Research Institute, National Dairy Research Institute and Central Soil Salinity Research Institute are some of the other institutions under the Indian Council of Agricultural Research working on various problems of arid zone development.
3. The Geological Survey of India through its Quaternary Geology, Geomorphology and Environmental Geology Division (Desert Geology) has taken up six specific arid zone projects on - (i) Sand advance, (ii) Desert evaluation, (iii) Lake salinity, (iv) Luni basin, (v) Ghaggar basin, and (vi) Rann of Kutch. Through a programme of detailed geomorphological mapping of the arid tracts by means of intensive field work, this division is providing basic information on geological, geomorphological and geochemical aspects of the arid zone relevant to the movement of sand, salinisation, relationship between landuse and geologic/geomorphic characteristics and palaeoclimatic evaluation. This is in addition

to the preparation of detailed geological maps and reports on mineral evaluation and the first geohydrological map (1969) prepared by the Geological Survey of India on the basis of extensive field studies.

4. The Botanical Survey of India and Zoological Survey of India have taken up systematic explorations in the arid and semi-arid tracts in order to build up a detailed inventory on the flora and fauna in the desert region.
5. The Central Salt and Marine Chemical Research Institute at Bhavnagar is primarily concerned with problems of desalinisation of water, utilisation of solar energy and development of economic products from naturally occurring brines in the Rann of Kutch and the offshore areas of the arid zone.
6. The Central Groundwater Board, after it took over complete groundwater surveys from the Geological Survey of India, has been continuing systematic geohydrological surveys and explorations in the arid zone.
7. The Indian Meteorological Department, Poona provides the network of basic meteorological data pertaining to rainfall, temperature, wind parameters and evaporation for the arid and semi-arid tracts of the country. This department is carrying out research on various aspects of desert meteorology with special reference to the Thar desert. A Drought Research Unit under this department conducts systematic studies on all climatic aspects of chronically drought prone areas of the country. It studies agroclimatology of drought, drought predictions, fluctuations in aerial extent of drought, and synoptic features associated with drought, duststorms and rainfall trends.

The Central Water Commission, Ministry of Agriculture and Irrigation has undertaken detailed studies on appraisal and promotion of irrigation facilities in drought prone areas. It has also been associated with the activities of the Technical Advisory Committee on Agroclimatic Study of Droughts set up in the Meteorological Department.

8. An International Crop Research Institute for Semi-Arid Tropics (ICRISAT) has been established at Hyderabad to provide support for intensive research on various aspects of dryland agriculture.

   The University of Jodhpur (Desert Studies Centre), Agricultural Universities of Gujarat and Haryana and the Agricultural College of Udaipur University have taken up specific research oriented problems of the arid zone and are also helping in imparting education on arid zone problems.

9. The Institute Francais, Pondicherry has contributed through the preparation of the regional vegetation maps pertaining to Rajasthan and Gujarat in collaboration with Indian Council of Agricultural Research. Recently, the Physical Research Laboratory, Ahmedabad has taken up programmes, in collaboration with Central Arid Zone Research Institute and Geological Survey of India, for dating and correlation of caliche from the desert tracts. The Institute of Palaeobotany, Lucknow and the Physical Research Laboratory, Ahmedabad have carried out palynological analysis of samples from the desert tracts.

10. The Survey of India provides the basic topographical maps of various scales. The National Remote Sensing Agency and Indian Space Research Organisation have the basic infrastructure and know-how for undertaking necessary programmes for interpretation of satellite imagery and application of remote sensing techniques.

11. The basic responsibility of implementing

the results of survey, investigation and research for effective management of the arid zone rests with various departments of the state governments. For instance, in Rajasthan, programmes for introduction of rationalised dryland farming, improvement of farming techniques, groundwater exploration, prevention of soil erosion, afforestation, creation of shelterbelts, management of livestock, dairying and wool production have been undertaken by respective departments concerned with agriculture, forestry, groundwater, animal husbandry and sheep and wool. The Irrigation Department has implemented small and medium irrigation schemes in the state while the Indira Gandhi Canal Board is responsible for the implementation of the Indira Gandhi Canal Project which is expected to introduce extensive agriculture into the western arid tract. Similarly, there is a strong infrastructural base for implementation of arid zone management programmes in other regions.

12. The Desert Development Board and the Commissioner for Desert Development are responsible for coordination of different programmes including relief measures for the drought affected areas. At the national level, the Ministry of Agriculture and Irrigation is responsible for coordination of various activities towards agricultural development in the country. For integration of environmental concern in development programmes, a National Committee on Environmental Planning and Coordination (NCEPC) has been constituted. Under the terms of reference assigned to it, one of the major tasks of this Committee is promotion of research in environmental problems. The NCEPC functions through two subcommittees, namely the Environmental Research

Committee (ERC) and the Indian National Man and Biosphere Committee (MAB) to assist the Department of Science and Technology in sponsoring research activities in areas of environmental concern.

The Indian National MAB Committee is in consonance with the worldwide Man and Biosphere Programme of the UNESCO. The National MAB Programme focuses its attention on ecological aspects of environment and has accepted specific project areas relating to the effects of human activities on the biosphere including landuse practices on grazing lands (from temperate to arid areas) and dynamics of arid and semi-arid ecosystems.

b. Drought Prone Area Programme (DPAP)

A special programme has been launched in the country since 1970-71 for the development of areas chronically affected by drought. Most of the districts in the states of Rajasthan, Gujarat and Haryana forming part of the great Indian desert are covered under this programme. The programme has basically two objectives-(i) Restoration of the derelict ecosystems and promotion of ecologically integrated development, and (ii) Generation of income and employment for the local population, especially the small and marginal farmers and agricultural labourers. The strategy is to improve the economy of these areas through a package of infrastructural and on-farm development activities with the objective of optimum utilisation of land, water, vegetation and human and livestock resources of these areas.

The main thrust of efforts is towards soil and water management, sand dune stabilisation, creation of windbreaks, development and management of the pastoral economy of these areas through a set of supporting and interlinked schemes of groundwater development and restructuring of cropping pattern and landuse practices. Economic water use and management techniques and systems are being stressed upon and developed. Agricultural extension machinery is being suitably geared to guide and motivate local population to adopt improved agricultural practices and livestock rearing.

Stress is laid on raising the productivity of livestock through an integrated programme of breeding, feeding, health cover and marketing of livestock produce. In order to meet the shortage of feedstuffs, schemes for pasture improvement, fodder development and fodder banking have been taken up in denuded areas, linked with the schemes of runoff management and utilisation of irrigation for fodder production. Pilot schemes for settlement of nomadic population are also being taken up. A cattle mortality fund has been created for the benefit of livestock breeders.

Soil and agroeconomic surveys are being organised for rationalising landuse practices and optimising the utilisation of natural resources. In order to involve the local population, particularly the tribals, in adopting modern or exotic technologies, action oriented development-cum-research and training programmes are being supported under the programme.

c. Integrated Rural Development Programme

The Integrated Rural Development Programme has been undertaken in various parts of the country. This programme covers some areas in the arid and semi-arid regions of Rajasthan, Gujarat and Haryana. Various aspects of agriculture, small scale industry, marketing, rural housing, clothing, education, health and family welfare have been dealt with under the programme. The major objective of this programme is the transfer of science and technology for improvement of economic and environmental conditions of rural settlements including those in the desert regions.

d. Desert Development Schemes

(i) *Rajasthan:* To stabilise the agricultural economy and initiate its growth, the following schemes were initiated in May 1970 for execution in Barmer district-(i) Rehabilitation of forests on hills (12,500 ha), (ii) Grassland development for fodder banks (2,000 ha), (iii) Development of pastures (6,000 ha), (iv) Reclamation of saline soils (3,000 ha), and (v) Windbreak plantations (5,000 km of rows).

The scheme for rehabilitation of forests on hills has covered a considerable area with kumat *(Acacia senegal)*, dhoora *(Anogeissus pendula)* and bushes to protect the area against grazing and browsing. The trees are now reestablished and the ground is covered with grasses and bushes. The resulting scrub forest has provided fuelwood from dead and dry fallen wood in addition to grass and grazing facilities. On a rotation of 40 years, each hectare will yield 200 quintals of fuelwood. In addition, two quintals of grass is made available annually from the fifth year.

Under the scheme for development of pastures, controlled and rotational grazing has been introduced. Some of the areas have been reseeded with perennial and nutritive grasses like dhaman *(Cenchrus ciliaris)*, kala dhaman *(Cenchrus setigerus)*, karad *(Dichanthium annulatum)* and sewan *(Lasiurus indicus)*. Moreover, in some of the pastures various top feed species have been planted.

The programme for reclamation of saline soils is intended to convert these lands into productive lands for cultivation by planting salt resisting plants. Vilayeti babul *(Prosopis juliflora)* and babul *(Acacia nilotica)* are now fairly well established. Windbreaks in multiple rows of suitable tree species of vilayeti babul, Israeli babul *(Acacia tortilis)*, farash, neem *(Azadirachta indica)* and siris *(Albizzia lebbek)* are being planted along all important roads, railway lines and around tubewells. The windbreaks will protect roads and railway lines from being covered with sand and check wind erosion in adjoining leeward lands.

In the Jaisalmer district of Rajasthan, schemes have been launched for cultivation of green fodder in 200 ha, pasture development in 3,000 ha and raising of one hundred wood lots and two nurseries. Investigations have proved the existence of aquifers with potential of installing several tubewells with an average discharge of 150,000 litres per hour. The exploitation of this groundwater is expected to help green fodder cultivation in this area. The Government of Rajasthan has undertaken a pilot project during 1973-74 for groundwater utilisation. The targets of this project are to undertake fodder production in 300 ha, pasture development in 750 ha, organisation of milk producers cooperatives in 25 villages and installation of a chilling plant.

The Indira Gandhi Canal Project, with a capacity of 524 m^3/sec, is a major irrigation scheme which is expected to bring about significant transformation in the desert ecosystem. Construction of about 650 km long main canal with branches spread over 6,300 km is intended to provide irrigation facilities to a command area of 1.35 million ha. On completion of the canal, irrigation will be provided to nearly 30 per cent of the cultivated area. The project area has since been divided into uniform sizes for distribution amongst landless farmers. In order to prevent overgrazing and to ensure the success of sand dune stabilisation programme, uncommanded (high dune) land is not allotted for human settlement. Steps have also been taken to ensure provision of irrigation facilities prior to allotment of land for farming.

(ii) *Haryana:* The programme of desert development in Haryana was initiated during 1969-70. Agriculture, minor irrigation and forestry are the major components of this programme. The biggest step that has so far been undertaken towards arresting desertification in Haryana is the spread of irrigation facilities. This has enabled the adoption of measures for reforestation and seeding of grass for stabilisation of sand dunes. In order to improve the moisture regime of the area, the Government of Haryana is now spending a major portion of its funds on irrigation activities. There are large areas where the topographical features do not permit irrigation through gravity flow. The government has initiated projects for lift irrigation in such areas.

To meet the acute shortage of water for drinking and irrigation purposes, schemes for percolation bunds have been approved by the Desert Development Board under the minor irrigation programme. As a result of construction of these bunds, the land below the bunds has been reclaimed for cultivation with a rise in the water level in the wells in an area of 39 to 52 km^2. The water in the wells, which was highly saline before, has improved in quality and is now within the permissible quality limits. The areas enclosed by the bunds could even grow a crop of wheat with the stored moisture.

Significant additions to forest area in the desert tracts of Haryana have been made through several programmes. An area of 36,983 ha is now under protected forests. The activities under the forestry scheme include afforestation on hills and nonarable areas in the plain, fixation of sand dunes, setting up of windbreaks in agricultural tracts and pasture development.

(iii) *Gujarat:* The arid areas in Gujarat lie contiguous to the arid areas of western Rajasthan and have similar conditions. Projects on minor irrigation, soil conservation and afforestation have been undertaken under the desert programme in Gujarat. The programme for minor irrigation includes construction of check dams *(adbandhi)* and tubewells. The check dams conserve water and moisture by inundating the enclosed area which, in turn, helps to leach the salts. These are expected to benefit an area of 766 ha. Under the tubewell scheme, 16 sites were explored, of which 13 have proved successful. When completed, they are likely to benefit 1,040 ha of culturable command area. Under the soil conservation programme, contour bunding has been done in over 3,000 ha.

A new technique of afforestation is now under trial. This consists of deep ploughing, contour bunding and planting of seedlings. This technique is reported to have increased the survival percentage of plantations to 60 on an average. It has been reported that the plants have come up well on the higher slopes, but they have stunted growth in the valleys where salts accumulate. The problem of keeping the salts away during the initial period of plant growth has to be solved. Construction of shelterbelts along roadsides, creation of village forests and fodder banks are some of the important activities to be undertaken for increasing vegetal cover. In the next 25 years, it is proposed to raise every year a desert border plantation in over 500 ha, shelterbelts in 100 km, village forests in 200 ha and irrigated plantation in over 50 ha.

e. Study Team Reports

A multidisciplinary team of scientists (1972), under the auspices of the Indian National Science Academy, made an on-the-spot study of certain aspects of western Rajasthan desert. The various measures for different areas as recommended by the study team include the following aspects:

1. Areas having or liable to have irrigation:
   - i) Development of surface irrigation, and
   - ii) Development of windbreaks and shelterbelts;
2. Areas which cannot be covered by surface irrigation:
   - i) Accelerated groundwater investigations,
   - ii) Sand dune stabilisation,
   - iii) Pasture development and regulation of grazing,
   - iv) Improved dryland farming techniques,
   - v) Animal husbandry,

vi) Organisation of service cooperatives, and

vii) Crop and animal insurance; and

3. Needs for research and development:
    - i) Studies of arid zone soils and adjustment of landuse.
    - ii) Improvement in meteorological studies,
    - iii) Development and perfection of remote sensing investigations,
    - iv) Interdisciplinary research and international cooperation with UNESCO Programme on Man and Biosphere,
    - v) Programme of training and education of desert techniques,
    - vi) Establishment of a computer centre for the interpretation of data and the application of systems analysis in environmental research, and
    - vii) Special investigations - sand dunes, water balance, geomorphological studies, crop losses, stability and functions of the ecosystem, integrated studies of the desert ecosystem, utilisation of wind and solar energy, scope for expanding mineral-based chemical industries and saline water conversion.

The National Commission on Agriculture (1974), set up by the Government of India, has made detailed recommendations on the management of desert areas in the country. The recommendations of the Commission on various aspects are outlined as under:

1. Conditions should be created to enable the nomadic people to lead a settled life. The migratory system of rearing cattle and sheep has led to higher mortality, low yields and unsystematic breeding. Higher percentage of illiteracy amongst the desert dwellers may also be accounted for their migratory livelihood;
2. Pasture development, regulated grazing and creation of grass reserves should constitute an important programme for the rehabilitation of the desert. Rotational grazing and grass reserves have to be

planned in fairly large blocks, each of a minimum size of 200 ha. Unirrigated land should not be parcelled out in small bits to the landless people but should be consolidated in large blocks for pasture development;

3. The desert area, even on rehabilitation, would not be able to support the present sheep and goat population. A progressive reduction in the number of goats, within 25-30 per cent of the sheep population, is recommended. The number of sheep should not be increased but improved through better breeding. In view of the importance of animal husbandry in the desert area, it should be aimed to utilise about 30 per cent of the irrigable area for growing fodder crops;
4. Nature has endowed the desert areas with hardy grasses and shrubs, which are able to survive in arid conditions with their deep root systems. Grasses like anjan *(Cenchrus setigerus)*, dhaman *(Cenchrus ciliaris)* and sewan *(Lasiurus sindicus)*, which grow in these areas, have a fairly high protein content and are relished by the livestock. The shrubs yield various edible berries. A few tree species, notably khejri *(Prosopis cineraria)*, provide top feed for camels, sheep and goats. These are heavily lopped for fodder and fuel. The phog *(Calligonum polygonoides)* is a valuable bush in the desert. The portion of it above the ground provides fodder and the roots below are dug out for fuel. Digging of phog has become a regular vocation and provides employment to a large number of people. The digging up of phog roots loosens the soil resulting in accelerated wind erosion and dune formation. To check such activities, alternative sources of fuel and livelihood need to be provided.

The desert area should be selfsufficient in the matter of fuel supply to the extent possible. The major activity for plantations should be confined to the irrigated parts of Indira Gandhi Canal command areas. Suitable shelterbelts and windbreaks should also be established to minimise the desiccating effect of hot winds and reduce sand castings. At places of cattle concentration, farmers and cattle breeders should be encouraged to install cowdung gas plants to ease the fuel problem and to ensure availability of the residue as manure;

5. All shifting dunes in the command areas of canal irrigation must be stabilised to prevent sand castings on arable lands. Grazing of livestock on these dunes should also be restricted;
6. Much of the prosperity of the desert areas would depend on the judicious use of the available water resources comprising rainwater, groundwater and surface water. To make fuller use of the available water resources, all known methods of water harvesting should be promoted wherever suitable conditions obtain. After meeting the important requirements for domestic use and industries, groundwater, wherever available, should be developed for growing high value crops and orchards. Irrigated grass farms for fodder banking would not be feasible on tubewells due to high cost of water.

   The irrigation policy should be to cover as large an area and as many farmers as economically possible. High intensity need not be aimed at; and
7. A long term plan for laying electrical transmission lines should be drawn for the desert areas according to developmental requirements.

The Commission has also made specific recommendations on cropping pattern, afforestation, reclamation of saline lands, cattle and dairy development, organisation of marketing facilities and demarcation of areas for Desert National Park. Based on the assessment of the present status and future potential, the Commission has recommended suitable measures for the development of major desert areas in the country (Rajasthan, Haryana and Gujarat).

f. Integrated Approach

During the past few years, worldwide activities on arid zone studies have been promoted by various agencies within the United Nations. In India, as a sequel to government's concern for desertification, steps were taken to establish facilities for undertaking basic and applied research on the problems of arid areas. This led to the setting up of the Central Arid Zone Research Institute at Jodhpur in 1959. Several other organisations like the Geological Survey of India, Department of Science and Technology, Desert Development Board, state departments, research institutions and universities have also been concerned with the desertification processes. Through international programmes and activities of national agencies, considerable experience has been acquired on different aspects of the problem. The scientific and technological bases for dryland agriculture and horticulture, grassland management, livestock farming, afforestation and water harvesting have been explored with a fair degree of success. Research and development efforts for the conservation and utilisation of natural resources, mobilisation of agricultural wastes and harnessing of solar and wind energy have indicated promising possibilities. Operational research projects have also been initiated in the arid areas to expedite effective transfer of technology.

However, despite considerable contributions and prodigious efforts of the concerned organisations, no significant breakthrough has yet been achieved. A major reason for this is the lack of an integrated approach. Most of the efforts for halting desertification and reclamation of arid areas have been sectoral in nature without adequate cognisance of the collateral issues. The available scientific information on the rational use of ecosystem resources is yet to be converted into action programmes. So far, the absence of a judicious resource utilisation policy inter alia land, water and energy has been the major impediment towards effective implementation of development programmes.

The action programme to combat desertification is a major task which covers activities under many disciplines and consequently several institutions both in the spheres of investigation and implementation. In view of its magnitude and complexity, it is important to have a comprehensive time phased plan of development with a clear idea of relative priorities and interdependence of various programmes. For instance, in dairy development or sheep husbandry it is necessary to raise sufficient fodder. This will necessitate controlled grazing, raising of green fodder and planting of leguminous shrubs wherever possible.

The pace at which the antidesertification measures can be carried out will depend on the availability of resources of man, material and money. There are constraints on the supply of a number of essential materials. These are to be kept in view while formulating any programme.

The most urgent step in the antidesertification programmes is to check further deterioration of arid and semi-arid areas. Diverse technologies are now available to put the land to the best use depending on its capability. The success in transfer of these technologies would depend on a coordinated endeavour of the concerned organisations for implementing massive extension programmes. The approach should be an integrated one in which measures involving technological adaptations and environmental management are linked with social and economic conditions.

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THE LIK RIVER OF THE RAJASTHAN DESERT: ITS SOURCE, COURSES AND PRESENT CONDITION

Amal Kar

I. ABSTRACT

Studies with the help of remote sensing techniques and field investigation on the Lik, which is the westernmost tributary of the Luni, have indicated that the origin of the river is in the ranns of That and Ujlan, although its present course is shown to originate from the hills of Bhaniyana. Some of the former courses of the Lik have been traced to indicate its past pluvial environment. The major cause of the present decadance and partial obliteration of the river is aridity.

II. INTRODUCTION

One of the very few right-bank tributaries of the Luni, the Lik river is now in the process of obliteration. While high sand dunes along its banks have restricted its defined course, formation of new barchans and barchanoid dunes across its course at several localities are obliterating parts of it. Yet, the morphological characteristics of the river indicate that the river was of considerable size in the past, with a far wider catchment than at present, and the local folklores suggest that it was a stream of some consequence. No study has yet been taken up to explore its source and to trace out its courses. The aim of the present article is, therefore, to trace its origin. its former courses and also to indicate the the causes of its present decadence. The study was carried out with the help of available aerial photographs, Landsat imagery and extensive field survey.

III. THE SOURCE AND FORMER COURSES OF THE LIK

In all the available topographical sheets the Lik has been shown to originate from the low rhyolite hill ridges to the west of Bhaniyana in Jaisalmer district and flow past Dantal, Phalsund, Gira and Santara until its course is lost to the south of Jund, approximately 20 kilometres to the north of Mekarna on the Luni. Moreover, in its upper reaches, especially between Bhaniyana and Phalsund the river's course is shown as disjointed segments, indicating gradual obliteration of the stream in this part. The total length of the stream from the hills of Bhaniyana to its supposed confluence with the Luni near Mekarna is 118 kilometres, with an average gradient of 1 in 691.

That the stream may have its origin somewhere to the north of the Bhaniyana hills became apparent during field survey and interpretation of aerial photographs and Landsat imagery. The area to the north of Bhaniyana is more or less flat with shallow sandy colluvial soil over most part and few rocky ridges and pediments, especially around the saline 'ranns' (playas) of That, Jhalaria and Pokaran. Detailed studies on these and other ranns of the area indicated that although they behave like areas of internal drainage with their own rocky catchments, almost all of them have an outlet. The rann at That has an outlet to the south near Marwa, while that of Jhalaria has one near Ujlan. Even the rann at Pokaran, which is fed by the water from the ranns at Dediya and Lawan, seems to have an outlet to the south, although it needs further confirmation. When the flow pattern from the ranns at That and Jhalaria were reconstructed it was found that the rann at That used to contribute to the Lik through the vicinity of Marwa, Teliwara and

Choudhari-ka-Dhani, while the Jhalaria rann used to drain out through Ujlan and then meet the course mentioned above near Marwa (Fig. 1). Subsequently the Jhalaria rann found another exit to meet the Pokaran rann in the north.

It is thus apparent that the source of the Lik was not near Bhaniyana, but in the ranns of That and Ujlan. Even now when there is abnormally high rainfall in the area the two ranns are said to drain out to the Lik, thus substantially increasing its discharge. However, such occasions are extremely rare and the river is in flow once in 30 to 50 years. The moderately deep alluvium along the Lik, on the other hand, indicates that the river was a major tributary to the Luni during a past pluvial phase. It had its own small tributaries from the rocky uplands, both in the east and the west. One of the major streams feeding it from the east was through the vicinity of Nathrau, Kanodiya, Asalai, Ratariya and Vijaniyan-ki-Dhani, ultimately joining the Lik to the south of Dantal. This stream had another confluence with the Lik near Phulasar. However, unlike the Lik the course of this stream is now totally buried and its alluvium is overlain in most parts by parabolic sand dunes of 10 to 35 m height. It is possible that the Saraswati, traced formerly by Ghose, et al (1980) in the region, did also occupy this course formerly. The stability of the dunes in the region and the presence of $CaCO_3$ impregnated layer (Kankar pan) within the alluvium are the indicators of the ancestry of this buried stream.

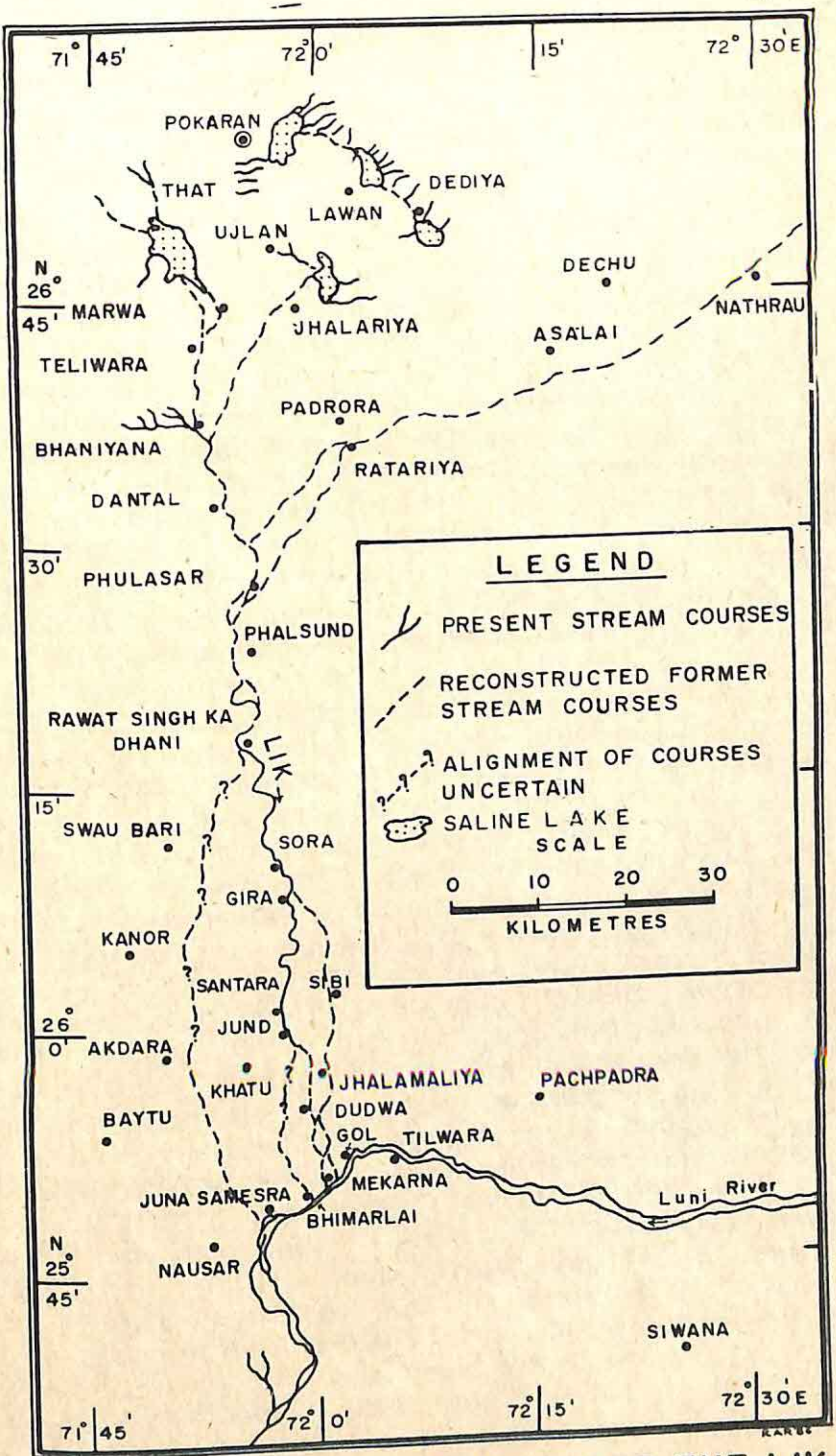
The flood plain of the Lik was a wide one becuase of the shifting nature of the river. Although over most of the area occurrence of high sand dunes restrict the collection of relevant information on the nature of sediments, sampling at selected sites indicated that the width of the flood plain was more on the right bank side of the present stream course, because it is on this side that the stream reached its farthest limit. For example, near Gira the width of its alluvial plain on the right bank side is approximately 15 to 17 kilometres, while on the left bank side it is about 5 to 7 kilometres wide. The alluvium thickness, however, generally varies between 60 and 120 cm and is covered with varying thickness of aeolian sand.

The westernmost course of the Lik could be reconstructed from near Rawat Singh-ka-Dhani and through the vicinity of Swau Bari, Kanor, Panavra and Akdara. It used to meet the Luni somewhere between Juni Samesra and Nausar. The easternmost course could be reconstructed from near Gira and through Sibi and Jhalamaliya to near Gol where it used to meet the Luni (Fig. 1). Within this limit the river shifted several times and ultimately came to its present course.

As mentioned earlier, the course of the river is very much indistinct to the south of Jund. However, from detailed investigation it has been possible to trace it through the east of Dudwa and then through Gol railway station to Mekarna where it used to meet the Luni. Another major confluence of the river with the Luni was at Bhimarlai from where the former course of the river could be traced upstream roughly through the vicinity of Khawas ka-Nada and about two kilometres west of Dudwa to Jund (Fig. 1). In this southern part some minor channels from the hills to the west of Jund and Khatu did also contribute in the past to the maintenance of the Lik's courses.

IV. DISCUSSION

The major cause for the gradual disappearance of the Lik's course is aridity. As indicated in the studies of Goudie, et al (1973), Singh, et al (1974) and Ghose et al (1977) the desert in Rajasthan underwent at least two major wet phases, each one followed by a major dry phase (including the present one) during the last Quaternary period. It is probable that the integrated drainage system of the Lik existed during a major wet phase around



THE SOURCE AND COURSES OF THE LIK

40,000 years B.P., when much of the alluviation took place. The succeeding prolonged dry phase dessicated the plains and created high sand dunes, obliterating many drainage lines in the process. The stability of the dunes, the evidence of two distinct phases of dune building activity in them and the compactness of the older form in them clearly indicate that another wet phase invaded the region subsequent to this period of main dune formation and the age of 10,000-3,800 years B.P., arrived at by Singh, et al.. (1974) for the second wet phase from elsewhere in the desert, could be tentatively fixed for it. The channel processes might have gained some prominence during the period, although restricted by the increasing sandy nature of the terrain. It is suggested that while the Lik maintained its presence through shifting courses during those phases, the tributaries joining it could not do so and were gradually buried under aeolian sand.

During the present dry phase even the Lik is facing obliteration due to extremely rare flow and advancing fronts of the reactivated high dunes, especially to the north of Phalsund and near Rawat Singh-ka-Dhani, Sora, Utarni and Santara. At most of these places such reactivation has led to engulfing of a part or the whole of the river cross section by the dunes and even their movement across it. Consequently the river bed is hardly able to maintain its true fluvial character. The dominance of aeolian process has resulted in a mixing of the coarser fluvial and finer aeolian sands, and their reworking has produced small isolated moving sand mounds of about 1 m height within the bed. Yet the banks of the river could still be recognized as 1 to 3 m high cliffs with associated strath formed of $CaCO_3$ concretion of riverine sand, aeolian sand and other finer particles, over which the high sand dunes have formed. The width of the river varies generally from 500 to 1000 m. In the extreme cases 3 to 5 m high barchans and barchanoid dunes have formed in the river bed, especially around

Dantal, Phulasar, Phalsund and Rawat Singh-ka-Dhani. Thus the twin factor of dessication and increased aeolian activity is leading to gradual obliteration of the surviving course of the Lik.

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DESERTIFICATION PROCESS UNDER DIFFERENT LANDFORMS USING REMOTE SENSING TECHNIQUES IN PALI DISTRICT

P.C. Vats

I. INTRODUCTION

Over past thirty years (1951-81) the population has increased very rapidly. Pali district registered higher growth rate (31.12 per cent) as against overall national growth of 24.75 per cent. Similarly the animal population has also increased resulting in the per head decline of grazing area to 0.03 ha. It is very low as compared to other district of western Rajasthan. This increasing human and livestock population pressure has disturbed the ecological balance and as a result desertification escalates and environmental deterioration follows. The different ecosystems have been degraded by the accelerated desertification process of water erosion, wind erosion/deposition, salinity/alkalinity, flood and industrial population. Keeping in view the importance and seriousness of the problem the present study was conducted by employing remote sensing techniques and ground truth, The salient findings of this study have been presented in this paper.

II. METHODOLOGY

Study on the desertification process under different landforms was conducted with the help of aerial photographs of 31,000 scale, T.M. of 1: 50,000, black and white land = sat imageries of 500,000 scales, Survey of India toposheets of 1:250,000 and 1:50,000 scales and field surveys. Data on morphological changes like water erosion, wind erosion/deposition, salinity/alkalinity and floods under different landforms were recorded in the field. The informations for the comparative study were also collected from the toposheets of 1934, aerial photographs of 1958 and landsat imageries of 1974.

III. DISCUSSION

The desertification processes in different ecosystems i.e. fluvial and aeolian have been discussed below—

1. Desertification of the fluvial ecosystem:

Interference of man in the nature such as cutting of trees, grazing of animals and construction of tanks and canals across the courses of prior drainage channels enhanced the fluvial geomorphic processes which created the sheet, rills, gullies, salinity, flood and polution hazards. About 31.35 per cent area of the district has been desertified in the fluvial ecosystem.

(i) WATER HAZARDS:

Due to torrential rainfall and rapid run-off water erosion in the form of sheet, rill and gully is common in the hills, rocky gravelly pediments, buried pediments, flat older alluvial plains and obstacle sand dunes. The cutting of the trees, over grazing of animals and unscientific cultivation have disturbed the surface stability and as a result, the surface soil is washed off with the exposure of the underlaying kankar pan. Because of these hazards a considerable land has been desertified and the productivity of these ecosystem has decreased. The total area affected by water erosion hazards is 3884.92 sq. km (31.35 per cent) in the forms of rills and gullies. The rills are 0.25 to 2.5 m in depth and 1 to 2 m in width and the gullies are 2 to 5 m in depth and 3 to 10 m in width. Slight to moderate sheet to rill and moderate to severe sheet to rill hazards occur in older alluvial plains, rocky pediments and buried pediments cover 2228.60 sq. km area (17.99 per cent) of which maximum 521.25 sq. km occurs in the older alluvial plains. Rill and gully hazards have turned fertile lands into bad-lands.

(ii) SALINITY HAZARDS:

In this district salinity largely occurs in the flat older alluvial plains, younger alluvial plains and buried pediment plains. The construction of irrigation reservoirs at Sardar Samand; Kharda Chpora, Hemawas and Nayagaon has resulted into water logging, capillary rise of the sub-surface salts and spread of salinity in the adjoining agricultural fields. (Tables 4). The excess irrigation from saline water having 6-10 m mhos/cm total soluble salts has affected large part of the district. Slight to moderate salinity has affected 305.70 sq. km area of sandy undulating buried pediment plains, saline older alluvial plains, saline younger alluvial plains and water bodies. The salinity of moderate to severe intensity has desertified 489.05 (3.95 per cent) sq. km of saline older alluvial plains and water bodies. The severe to very severe salinity hazards has affected 38.09 (0.31 per cent) of shallow saline depression and a very small part near Kharda village located in the saline older alluvial plain.

(iii) FLOOD HAZARDS:

Unlike the humid and sub-humid parts of India heavy floods are not common in the arid and semi-arid regions of western Rajasthan. A low pressure monsoon depression caused unprecedented torential rainfall during July 1979 in the Luni, the Guhiya and the Bandi catchments. During a period of 4 days (i.e. 16th to 19th July 1979) the area received rainfall of 600 to 900 mm which is far above the annual average of 367 mm.

Due to this flood of high velocity conspicuous morphological changes in the river beds, younger alluvial plains and older alluvial plains took place. Sizeable area along the river channels were damaged either by scoring meandering or sand deposition. At several places i.e. Sanjee, Bhaton ki Dhani, Bhakri to Bhadrayan the sand was deposited on good agricultural land in the form of sand mounds and sand sheets varying in magnitude from 20 cm to 1 m. In these villages at several places the good agricultural land has also been eroded upto the Kankar pan. About 200 villages were affected and out of which 195 were severely affected and submerged into the water. In these affected villages about 1800 houses or huts were damaged.

Due to the morphological changes in the form of erosional and depositional hazard, the productivity of flood plains decreased. About 95 per cent of Kharif crops were damaged. This flood period was abruptly followed by a drought period in the entire district. As a result the Kharif crops production was practically negligible e.g. Bajra and Jowar 45 and 9 tons, respectively. The comparative study conducted by Dhir et al. (1982) revealed that there is a significant variation in the characteristics of original sediments and the fresh sediments deposited by the flood. The fresh sediment have 3 to 4 per cent clay and less than 1 per cent silt and around 3.5 per cent moisture retention capacity. The original soils contain 6 to 10 per cent clay and 4 to 7 per cent salts and 5 to 20 per cent moisture retention capacity. (Dhir et al. 1982).

As per available material, the status of fresh flood sediments is comparatively lower than original buried soils (Table 1).

Table 1. Available nutrient status of fresh sediments and original soils.

	Fresh sediments			Original soils		
Location	Organic carbon (%)	PO 25 (kg/ha)	KO 2 (kg/ha)	Organic carbon (%)	PO 25 (kg/ha)	KO 2 (kg/ha)
Luni to Kankani on	0.06	13	92	0.17	25	495

Dhir et al. 1982

(iv) POLLUTION HAZARDS:

The textile industries of Pali which are very important for the economy of the area, are causing health hazards to the local public. These factories discharge huge amount of liquid waste which include the metals like vanadium and nickel bleeching powder, castic soda and sulphuric acid. A huge amount of effluent water of these factories is poured into the Bandi, an ephemeral river, excepting for a few days of rainy season. The effluent water of the industries is highly contaminated (Table 2 & 3) and remained stagnant and recharge the wells located either sides of the river. As a result the water of the wells of Malawas, Garwara, Leoria and many other villages located in the down stream have become saline/alkaline. "The wells which are located near to the effluent water which is stagnant since long show considerable faecal pollution MPN index varies from 9 to 64/100 mg, which is much higher than the permissible limit of 10/100 ml. All the wells located far away from the bed of the river or the stagnant effluent, the electrical conductivity varies from 783 to 1333 micromhos/m and pH values range between 8.1 to 8.7" (Singh, 1985).

Because of the polluted water the land use system in the younger alluvial plain of the Bandi river has been adversely affected. The water which is used for irrigation contains the anions like the chloride

Table 2. Results of chemical analysis of grab samples of raw effluents from some Textile Industries of Pali.

Sample Name of process(es)	Color and appearance	pH	Suspended solids (mg/l)	Oil and grease (mg/l)	Chemical Oxygen demand (COD) (mg/l)	Biological Oxygen demand (BOD) (mg/l)
Desizing	Cream yellow dirty turbid	12.80	1280.0	162.0	760.2	398.0
Bleaching	Cream yellow turbid	12.50	1185.0	142.0	818.7	547.0
Dyeing	Deep green turbid	9.85	395.0	36.0	833.3	657.8
Printing	Bricks red turbid	8.40	235.0	28.0	672.7	474.8
Finishing	Milky white turbid	7.50	680.0	64.0	710.7	476.4
Composit effluent (Desizing+Dyeing +Printing	Dirty green Turbid	12.50	325.0	81.0	935.6	571.8
Caustic treatment +Bleaching +Procion printing	Purple Fluorescent turbid	12.55	495.0	94.0	608.1	383.51

Sources: Mauria, 1986

Table 3 Qualitative analysis of entering in centralized effluent treatment plant of RIICO

pH	pH	C.O.D. (mg/l)	B.O.D. (mg/l)	T.D.S. total dissolved solids (mg/l)	P. Alk (Phenolph alkalinity (mg/l)	T. Alk Total Alkalinity (mg/l)	O.H. (mg/l)	CO_3 (mg/l)
Entering	10.0-11.5	992.1280	400-900	8600-10400	1900-3000	2800-4200	1000-1800	1400-2400

Source: Mauria, 1986

Table 4 Saturation extract composition of soil at Nayagaon

Depth in cm	pH 1:2	EC Saturation extract M/mhos	Na Mc/L	K Mc/L	Ca Mc/L	Mg Mc/L	Cl Mc/L	HCO_3 Mc/L	CO_3 Mc/L	SO_4 Mc/L
0-8	8.5	1.619	13.04	0.76	2.0	2.0	8.0	6.5	1.0	2.3
8-22	9.1	3.432	32.6	1.15	3.0	—	30.0	5.25	—	1.5
22-35	9.3	8.869	86.9	2.30	4.0	3.0	60.0	4.0	—	32.2
35-90	9.5	14.055	130.4	2.43	3.5	7.0	9.5	2.5	0.5	46.33
90-125	9.3	26.689	254.3	3.7	12.0	16.0	210	1.75	—	74.25
125-170	9.05	33.834	267.3	4.48	26.0	44.5	340	1.5	—	0.78
170-185	8.8	48.816	434.7	5.12	40.0	71.5	470	1.25	—	80.07

Source : Shankarnarayan (ed.) 1982

(298 to 1491 mg/lit), cronttes (11 to 55 mg/lit) and bicarbonates 112 to 495 mg/lit) (Singh, 1985). Due to the presence of these salt the land which was irrigated by this water has become very hard and thus a problem of sodicity has developed. Now this land is a waste land. The polluted water has also affected the productivity of the Bandi younger alluvial plains. Before 1971 when the textile industries at Pali were very few, the production of Kharchi wheat in that area was 20 to 22 q/ha, but now it has come down to 5-8 q/ha and of raya from 4 to 6 q/ha, has come down to 0.5-1.5 q/ha.

2. Desertification of the aeolian ecosystems:

Due to the over grazing, ploughing in wind direction during summer season, long fallow and continuous cultivation on land in the area, the wind deflation and erosion hazards in the form of sand sheeting (0.5 to 0.75 m thickness) and hummocks (1 to 2 m heights) have occurred. In this district 359.69 sq. km area of good agricultural land has been damaged by these hazards. Out of 359.69 sq. km area, slight wind deposition hazard covered 239.06 sq. km (1.95 per cent) area of the older alluvial plains. Moderate to severe wind depositional hazards affected 120.63 sq. km (0.97 per cent) area of the sandy undulating older alluvial plains.

IV. SUGGESTIONS TO COMBAT DESERTIFICATION PROCESSES

The following suggestions for better utilization and management of different ecosystems be considereds:

1. Soil and water conservations measures are urgently needed to control soil erosion and to conserve water resources. Suitable sites for the soil and water conservation have been suggested (Vats, 1983).
2. The small dunes or hummocks and sandy plains which are highly vulnerable to desertification processes should be completely checked from animal grazing and cultivations. The hummocks which are active should be checked by mulching with local plant materials. This should be followed by sowing grass seeds along mulch lines during the rainy season.
3. To avoid the menace of wind erosion/deposition hazards the deep ploughing in the wind direction during summer season should be discouraged. The ploughing should be done across the prevailing south-west winds.
4. To avoid salinity hazards there should be controlled irrigation

shallow soils and granite terrain and profuse irrigation should be stopped.

5. Controlled grazing should be introduced, if possible, grazing lands should be fenced.
6. The effluent water of the industries should be released in the river only after the proper treatment and removal of harmful salts.

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16

REMOTE SENSING APPLICATIONS FOR NATURAL RESOURCES AND DECISIONS MAKING

N.C. Gautam

I. INTRODUCTION

The digital information transmitted electrically from the satellite platform to ground stations can be utilised in a number of ways. Image for visual display can be synthesised from the data. Statistical information may be derived which quantifies such information as soil type, vegetation type, water quality, land use and some other pertinent geographic features. Crop inventories may be conducted very accurately and on a recurring basis throughout the growing seasons. Geomorphic features of interest, such as major fault, traces or drainage system may be delineated with the aid of satellite imagery. Errors inherently troublesome in traditionally ground based mapping techiques can be avoided by using satellite imagery to plot small scale map that actually portray reality.

By giving earth scientists the 'BIG PICTURE' satellite allows decision to be made concerning areas of large extent of remote location. These decisions can be based on accurate, easily accessible and constantly updated information provided by the Remote Sensing Platform.

1. Satellite

The first Landsat/ERTS (Earth Resources Technology Satellite) was launched on July 23, 1972. The name of the ERTS-1 was changed in January 1975 as Landsat - 1 (Land Space Application Technology or Satellite). Landsat - 2 was launched on January 2, 1975 and Landsat - 3 was launched on April 5, 1978 and files in a circular orbit 920 kms. above the earth's surface and circles the earth every 103 minutes or roughly 14 times per day with repetitive coverage every 18 days. A unique feature of the satellite because of the orbit, is that it views the earth at the same local time, roughly 9.30 a.m. at the Equator and each orbit cover a strip of the earth about 185 kms. in width. The distance between the successive strips would be about 2550 kms. at the equator, and progressively less at the poles. India is one of 35 countries, where remote sensing techniques are being used.

Landsat - 4 was launched on July 16, 1982 and Landsat - 5 on March 1984 with MSS and Thematic Mapper and circles the earth 705 kms. above the earth surface. It has repetitive coverage every 16 days and covers a strip of the earth surface about 185 kms. in width. At present Landsat - 5 is in operation.

2. Spot

The SPOT satellite was launched on 23 Feb. 1986. This satellite observes in three spectral bands (in the visible and near infrared portions of the spectrum) with a ground resolution of 20 metres and in a broader spectral band (Panchromatic black & white) with a ground resolution of 10 metres.

3. IRS-IA

Indian Remote Sensing Satellite (IRS-IA) was launched on 17th March '88. The payload system of IRS-IA comprises of 3 Linear Image Self Scanning (LISS) cameras, each of them working in 4 spectral bands, - 3 in visible and one in near IR. The first camera designated LISS-I provides a resolution of 73 metres and a ground swath of 148 kms. The second and third cameras designted as LISS-II A and LISS-II B respectively with a ground resolution of 36.5 metres and swaths of 74 kms.

4. Remote Sensing

Remote sensing is the acquisition of physical information from a source that is stationed some distance at far away. Instruments used to gather this information are called remote sensors. After the eye and telescope, film camera is perhaps the oldest remote sensor. They play an important role in the aerial photographic surveys of land, water and forests. Beyond the camera and the aircraft, spacecraft and new improved electro-magnetic sensors have come into use and the data thus received from these sensors are being used for different natural resources studies.

II. METHODOLOGY FOR NATURAL RESOURCES MAPPING

For analysis and interpretation of natutal resources two types of data are needed.

1. Basic data 2. Ground data

1. Basic Data includes : a) Satellite data b) Computer compatible tapes (CCTs) c) Aerial Photographs d) Toposheets e) Area map on any scale to transfer the details f) Local knowledge g) Reports etc.

2. Ground data

The ground data collection is very much essential to verify the interpreted classes and also to give the training sets to the computer for analysis and also to minimize the field work.

The whole study can be divided into three parts: (i) Preliminary work; (ii) Field work; (iii) Post field work.

(i) Preliminary work includes: (a) to see the limitation of the satellite data and to develop a criteria for the evaluation of classification system; (b) preparation of pre-field interpretation key; (c) preparation of field map; (d) classification adopted; (e) interpretation of different themes; and (f) size of unit to be plotted.

(ii) Field work includes: (a) selection of sample area for final checking and (b) its verification in respect of changes in the classification unit due to; (i) wrong identification (ii) fresh development, (iii) ambiguity in the definition, etc.

(iii) Similarly post field work takes into account (a) reinterpretation; (b) correction of doubtful areas, and (c) preparation of the final map.

III. SATELLITE DATA FOR NATURAL RESOURCE SURVEYS

The remote sensing technique has helped in the collection of various types of data of immense importance to geographers, geologists, forester, agronomists, hydrologists, soil scientists and experts of various other disciplines through the use of special sensors from satellite or aircraft. The repetitive nature of satellite imagery enables its use for many gainful purposes of mapping the natural resource surveys which are given below:

1. Geology and Geomorphological Mapping

Using satellite data in the form of imageries both in black and white and false colour prints, lineament/tectonics and landform association maps could be prepared by standard visual interpretation techniques. Large areas can be mapped within a short time due to the synoptic over-view. The greatest contribution of satellite imageries for geological studies has been in the field of structural analysis. Structural features which are not identifiable on the ground and some-times even on aerial photographs, have been identified very easily on satellite imageries because of thier regional coverage. Constructional and distributional landforms, landforms associated with the sub-aerial processes such as wind, water, ground water, glaciers, etc., specialised landforms and their implications on the existing physical and cultural processes could be studied properly using multidate satellite data.

2. Soil Mapping

Soils, one of the most renewable natural resources as the basis of food production are needed to be studied, observed, characterised, classified and mapped so that they can be put to maximum utility. Qualities of satellite such as synoptic view and repetitive coverage enable the soil scientists to carry out critical studies on soils using remote sensing techniques.

Maps showing association of soil sub-groups on 1:250,000 scale could be generated through computer using Landsat in the form of CCT in conjunction with computer implemented pattern recognition techniques. But by using aerial scanner data even high intensity soil maps could be prepared with sufficient ground data. This technique could be expected to augment the soil survey efforts but of course can not replace traditional soil surveying specially for preparing semi-detailed soil maps. However, soil maps produced by this techniques could undoubtedly form a base map for further detailed soil surveys.

3. Forestry and Vegetation Mapping

Remote sensing techniques with the computer facilities as available in NRSA enable for intensive-mapping of forest types such as evergreen, deciduous, bamboo forests, teak forest, degraded forest, etc., depending upon the region and species composition. Area under forest can also be calculated using computer facilities.

4. Hydrological Mapping

Identification and mapping of the water bodies like rivers, lakes, lagoons, tanks, ponds, bays, estuaries and reservoirs provide valuable information of source or location of water supplies for various purposes like drinking and other domestic needs, agriculture and live-stock population, etc. Upto-date information and change in water-bodies can be obtained using Landsat multidate data.

5. Land Use and Land Cover Mapping

Remote sensing technique has proved to be a rapid, economic and reliable technique in preparing small and regional scale thematic maps. Land Use and Land Cover mapping is one of the important thematic mapping work, where remote sensing techniques can well be applied for quick, accurate and economic mapping of Land Use and Land Cover categories. The categories that can be obtained from the remotely sensed data includes urban or built-up areas, mixed forest, ever-green and deciduous forest, scrub land, grass land, mixed hill plantation, crops fallow and barren land, surface water bodies like rivers, tanks, reservoir, lakes and canals. By virtue of satellite, capability of repetitive coverage the information about various land use and land cover categories can be updated at 18 days interval. Thus a map could be prepared showing existing information on land use and the changes that occur in land use which will be of immense value for regional planning. Using aerial scanner data high intensity land use (urban and rural) mapping, urban area analysis can be effectively done.

IV. ROLE OF REMOTE SENSING IN DECISION MAKING

The relationship of man to his environment and to the natural resources that sustain his life and activity involves a continuous series of major and minor decisions. Decisions are the determinates of a course of action. A sequence of decisions is the process by which we set the goals toward which organised society or individuals move and by which guideposts are established along the way. Thus, the purpose of decision-making is to set a goal or target for action and to guide along the route by which the goal is achieved.

The role of remote sensing in the decision process is merely to provide reliable information—at an acceptable level of accuracy, in a timely, cost-effective manner. The decision maker's goal is to make the right decision when it needs to be made.

Now question comes, what is a decison ? A decision is "the act or process of arriving at a solution that ends uncertainity or dispute". It is "the act of making a choice or judgement". It is a determination (position or conclusion) arrived at after consideration.

To start with it is important to recognise that man's relationship to his resources is extremely complex. As he strives to allocate, develop, use, manage, and monitor the resources so critically important to his continued existance, it is essential to appreciate the strong interaction and side effects that may result from each decision and action of any resource use and development program. It is a rare case where one decision and action program does not impact another; for example, agricultural development impinges on prime forestry or grazing lands with implications in watershed and wild life management. Urban and Industrial development or the setting of infrastructure may cause both beneficial and deleterious side effects on agricultural land use. And finally, extractive industry and poor land use practices in agriculture, forestry and grazing land management can cause extremely undesirable side effects on watersheds. In this complex setting, man makes his decision and takes action to extract his need and wants from the natural resources available to him. The long term results will depend on how rational and well informed are each of his decision along the way.

V. STEPS IN RESOURCE MANAGEMENT

A resource allocation, development, use and management, four major functions are essential to the decision and action process. These are:

- Inventory
- Analysis
- Operations
  - ... Planning
  - ... Implementation
- Monitoring

Remote sensing comes into play in the inventory and the monitoring functions. The role of remote sensing in the inventory function is obvious as a mechanism for developing information which is then analysed and fed into the decision and planning process. Remote Sensing's second role comes in monitoring which has as its purpose the five-tuning of the action or implementation programme.

The inventory requires some attention to the whole landscape and to all resource elements. In a complete analysis, maps are provided of the kind of resources and their geographic distribution with tabulation of areas. Monitoring function, on the other hand, rarely looks at the whole area. It is generally done on a restricted subsampling basis which focuses on measuring responses or reactions to the implementation programme—main effects, side effects and progress towards the goal.

VI. THE ROLE OF REMOTE SENSING

The role of remote sensing in natural resources decision making is, therefore, to provide the essential facts, to provide information that is relevant to each decision that is required to remove the causes of the problem while producing a minimum of undesirable side effects. As the sophistication of the sensor system increases, it tends to become more and more demanding of the analyst and his level of understanding of ecological condition and the ecological phenomena and processes that take place on and beneath the earth's surface. Thus one can get useful information about earth resources from satellite data of that particular landscape. Remote sensing is likely to be the most cost effective way to ensure sound decisions about an action programme because it reduces fieldtime, makes staff more effective, provides more timely and useful information or reduces the total project duration. The potential role of remote sensing in the decision process is high, where field or ground examination costs are very high, location of ground observation points are difficult or impossible of access, subjects of interest can be sensed or measured from a distance, and where time or staff are limited.

There are three areas of decision making in resource management Each of these three has its unique and different information requirements. These three areas are:

...Legislation, policy and broad planning

.. Resource allocation as to purposes and combinations of uses.

...Resource management at various levels.

Each of these three broad functional areas are multi-level in character with a unique information output being required for the decision made each level.

The scale of imagery used or of final map produced determines the amount of detailed information that can be provided. It should be noted that legislative, broad policy and planning decision, generally made by the upper executive, require small scale or broadly generated information elements. But as policy and planning decisions move from national to local level, higher degree of details are needed.

VII CONCLUSIONS

Thus Remote Sensing provides *needed information* particularly on natural resources at less cost, potentially at higher levels of reliability and in a more timely manner than conventional ground methodologies. The accuracy of the analysis should be checked and the nature and magnitude of commission and omission errors. Given this information, the decision maker can use the results and move ahead in the decision process.

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APPENDIX I

Report of the Workshop Deliberations

I INTRODUCTION

The University of Jodhpur, conducted the U.G.C. sponsored National Workshop in Recent Advances in Monitoring the Process of Desertification from October 27 to 3rd November, 1985. A total of 50 participants comprising the University and College teachers and researchers in Geography, Botany, Physics, Zoology, Climatology, Economics and Allied fields participated. In this workshop academicians from varied disciplines have assembled for the first time to present their comprehensive techno-scientific expertise in monitoring the process of ecodisaster. The participants and resource personnels came from almost all the geographical areas of India—North-East (Imphal), Sutlej-Ganga plain (Kurukshetra, Rohtak, Delhi, Aligarh, Lucknow, and Gorakhpur), the Deccan plateau (Hyderabad), coastal plains (Waltair), Gujrat plain (Baroda) and the arid and semi-arid plain of Rajasthan (Jodhpur, Jaipur, Bikaner, Ajmer, Didwana, Bhilwara, Ganganagar and Chittorgarh). The workshop activity was divided into several focal themes each including addresses, lectures, demonstration, tutorials, field and laboratory exercises and discussion on specific topics followed by practical sessions for direct handling and application of the techniques demonstrated.

II PURPOSE AND OBJECTIVE ACHIEVED

The main purpose of the workshop was to demonstrate present and future techniques of environment-watch system by using remote sensing-visual and computer aided techniques. The workshop also featured the conventional carto-numerical and field observation techniques in cross tabulating the known physical and human parameters. The participants were taught the use of sophisticated and advanced methods in class exercises, laboratory, and field sessions. It was designed to meet the growing need of the younger generation researchers and teachers to equip and formulate the advanced knowledge in environmental amelioration studies for hazardous areas. The approach was to offer practical training in handling the data by mutual interaction of the participants and resource personnels. The general objectives of the workshop were achieved in the following manner:

(i) The participants were acquainted with the present state-of-the art in measuring the process of desertification.

(ii) They were imparted basic skills in the use of cartographic and remote-sensing techniques by visual and digital analysis of environmental data of the Indian desert.

(iii) They were provided training in laboratory and field with perspectives and methods for planning and managing the eco-disasters.

(iv) They were equipped to devise and apply such techniques for testing the spatial-temporal dimensions of the natural hazard in their own areas.

(v) They were taught to perfect the techno-scientific knowledge in assessing, monitoring, storing, presenting and sensing the overall aspects of eco-units.

(vi) They were made conscious to understand the national and regional crisis in their respective environments and to react in a positive manner for ameliorating the supply of natural flow resources in fragile ecounits, and to spread the application of new tools and teaching materials for an inter-disciplinary research.

III TECHNICAL DELIBERATIONS

The workshop addressed the following focal themes during eight technical sessions.

1. THE CONCEPTUAL FRAME was provided by the Director in his welcome address (Recent Advances in Monitoring the Process of Desertification: Ecounit Planning), followed by the inaugural address of Dr. K.A. Shankarnarayan, Director Central Arid Zone Research Institute (Monitoring of Desertification: A conceptual frame) and presidential address by Prof. M. Shafi, Professor emeritus Aligarh Muslim University (Ecological Imbalances and food system). On 27th October, 1985 the session was chaired by Dr. S.N. Mehrotra, V.C.-University of Jodhpur. All the participants and resource personnels introduced themselves on the inaugural day. The cultural programme was presented by the students of Geography department.

2. THE BIO-PHYSICAL ENVIRONMENTAL ANALYSIS was deliberated in the morning session of 28th October through the

lectures and addresses of Dr. N.C. Gautam, Head Division of Land-use and Mapping, National Remote Sensing Agency, Hyderabad (Application of satellite Data for geographical studies). Dr. Surendra Singh, Geomorphologist, Central Arid Zone Research Institute, (Remote Sensing in Monitoring Desertification Process under Different Landform Ecosystems) and Mr. A.K. Sen, Head of the Cartography Division, *Central Arid Zone Research Institute (Environmental Degradation due to Desertification in Rajasthan Desert).

3. LECTURE ON CLIMO-EDAPHIC PARAMETERS were delivered by Dr. Y.S. Ramakrishna, Climatologist, Central Arid Zone Research Institute (Climatic Changes in Relation to Desertification), Mr. S.K. Saxena, Economic Botanist, CAZRI (Desertification in Western Rajasthan) and Mr. Nepal Singh, Soil Scientist CAZRI (Desertification by Soil Approach) on the afternoon session of 28th October.

4. The focal Theme, HUMAN FACTOR ANALYSIS was discussed by Mr. S.P. Malhotra, Head Division of Human Factor, ? CAZRI (Human Resource Assessment in Arid Zone of Rajasthan), L.P. Bharara, Economist, CAZRI (Animal Human Relationship and Desertification), Prof. A. Ahmed, Chairman, Centre for Regional Dev. Studies, JNU (Desertification in India: Social Causes and Consequences), Prof. Jagdish Singh, Univ. of Gorakhpur (Environmental Degradation) and Prof. R.N.P. Sinha, M.S. Univ. Baroda (Monitoring desertification and environmental assessment) in the lecture sessions from 29th Oct. to 1st Nov. 1985. They emphasized the priority of updating the methodology and techniques of environmental studies alongwith the other universal problems of population, pollution and poverty.

5. THE TUTORIAL AND LABORATORY work consisted of cartographic, remote sensing and focal theme discussions by the participants and resource personnels every day in the evening sessions. Specific demonstrations were presented by Prof. Jagdish Singh (Gorakhpur), Dr. N.C. Gautam (NRSA, Hyderabad), Prof. N. Sankhla (Jodhpur), Prof. M.M. Bhandari (Jodhpur), Dr. D.M. Bohra (Harare) and Prof. A. Ahmed (J.N.U. New Delhi).

6. THE FIELD EXERCISE AREA SESSIONS included the guided visits and on-the-spot studies of aridland landscape in the Central Arid Zone Research Institute, Photo-interpretation Laboratory, Kailana watershed and rangeland study, Operational Research

Programme in Daijar Village, Beriganga Nursery, Mandore gardens and Jodhpur fort and its environment.

7. On Nov. 2 the participants presented individual reports on SPECIFIC AREA STUDY AND ISSUES in environmental planning and amelioration. They emphasized the development of diversified strategies and strong coordination in monitoring the degradation of natural environment in different geographical situations of India.

IV RECOMMENDATIONS

The concluding session on 3rd Nov. 1985 was devoted on the workshop recommendations and award of certificates. The committee for presenting the recommendations was convened by Prof. Mohi-ud-din of Govt. College, Bhilwara and attended by all the participants and resource personnels. Specific resolutions in the form of workshop recommendation were discussed in depth and unanimously adopted. The workshop examined the physical, biotic and socio-economic factors in the process of desertification and perfected the recent tools and methods for monitoring such processes. It is recommended that—

(i) The desert space is an asset to the country and its optimal utilization should aim at ameliorating its physical, biotic and human environment.

(ii) All efforts should be directed towards a scientific triple land-use strategy underlining equal emphasis on agriculture, pasture development and plantation of Xerophytic and Mesophytic trees along the Indira Gandhi Canal Zone.

(iii) The integration of regional and local water management be given top priority with introduction of soil moisture conservation in dryland farming zone and vigorous management of micro-watershed, khadins and irrigated areas.

(iv) A commission on the education of desertification monitoring techniques be established in the department of geography, University of Jodhpur which will undertake the follow up actions and will coordinate scientific research with government organization such as Central Arid Zone Research Institute, Desert Development Programme, and the International Geographical Union. The Commission will be responsible for developing conceptual frames, field-cartographic-quantitative and remote sensing techniques, advanced tools and teaching materials for colleges and universities.

APPENDIX II

Participants note/Observation

1. Dr. H.M. Saxena,
   Head, Deptt. of Geography,
   Govt. College, Sriganganagar.

For proper use of available resources in desert regions as well as for integrated development planning following steps should be taken in its first phase:

1. that education of environment specially the desert ecology should be given right from primary classes. There is a need to educate public specially the rural people, scatteral throughout the region.
2. the question of desert expansion should be discussed and a final opinion be formed, irrespective of pre-determined notions.
3. separate development plans should be prepared for Arid and Semi-Arid regions. Similarly plans for those areas should be prepared where irrigation facilities are available.
4. for Indira Gandhi canal region, Ganga canal model of colonisation may be taken as a base.
5. Regional survey of resource potentialities should be conducted in order to formulate development plans.
6. there must be co-ordination between research agencies like CAZRI, Desert Development Authority, Birla Dev. Studies Centre, as well as of State Government.
7. for formulating the desert dev. plans care should be taken for social and behavioural pattern of the people.
8. there is a need for periodic evaluation of the results of plans implemented for desert development.

2. Dr. V.K. Sharma,
   Reader, Geomorphology,
   Kurukshetra University,
   Kurukshetra.

The resource personnel gave a good exposition of the State of existing environmental parameters in their various symbotic relations which give a typical character to the desert land-scape. The techniques and methodologies that have been used as parameters for the identification of desert environment, and accentuation of desert-like conditions within and in the fringe zone of deserts were explained in sufficient details.

However, the emphasis fell short of the techniques used for "monitoring" the process of desertification process. I feel efforts should be channelised towards quantification of the boundary conditions for a proper comprehension of the process of desertification. Such an approach will go a long way in predicting the state of fragile desert eco-system at any given point in time and space under the everchanging stress of technologic influences.

3. Dr. Sachidanand Sinha,
   Deptt. of Geography,
   M.D. University, Rohtak.

1. The evaluation of human and social factors in the process of desertification calls for a greater comprehension of the socio-economic and political institutions in time and space. There is no denying the fact that through these institutional fitters and channels the social man as an actor on the fragile stage of the desert ecosystem receives information which has a strong bearing on his behaviour. Man in his socio-economic and political milieux is at times in harmony with nature and at times in conflict. The nature of conflict may be coherently understood in the evaluation of the production systems and the means and relations of production. In this regard I suggest one must approach the problem of monitoring the process of desertifications from the point of institutional and structural dimensions of the desert society.

2. In the light of technogenic changes brought about by modern institutions a new dimension of conflict (between man and nature

among various segments of society and between communities in different stages of production nodes) has emerged. We have on one had, for example, the basic needs of people and on the other the commercial gains of society. Such conflicts have identified the course of desertification. Our task is to look closely into the natural course and consequences of such conflicts.

3. With respect to the culturation of marginal lands which has allegedly contributed to the process of desertification one must care to observe as to who cultivate the marginal lands and why ? Is the marginal land being cultivated by those who have been gradually pushed on to the margins of the socio-economic or by those who have the means of production and whose voracious appetite for greater economic benefits has accentuated the process of desertification ?

4. With respect to dissemination of technological innovations one must also look into the economics of innovations vis-a-vis the structural resistance which inhibit the process of diffussion. One must pose that if the innovation has an inherent but unintentional class bias its acceptance by a broad cross-section of society may not take place.

5. Lastly, I would suggest that the problems associated with the process of desertification needs greater pursuance and enquiry from the perspective of dialectical relationship between socio-economic and institutional process.

4. Dr. R.D. Gurjar II,
Rajasthan University,
Jaipur.

A few suggestions are made under the light of delibrations from CAZRI scientists and some others as following:

a) To avoid after effects of some programmes, a holistic view of the problem should be taken by the concerned scientists and administrator. The water logging problem near Suratgarh along the periphery of Ghaggar diversion channel depression witness this fact. So all studies conducted by state/central government scientists should be co-ordinated.

2. Solar energy should be utilized to meet at least the local fuel needs of the people.

3. There should be systematic demonstration of the technology

developed so far, so that people may participate relating to cultivation practices more particularly.

4. The DDP, MAB should be integrated to implement the programme of all govt. deptts.

5. The livestock development needs more care by introducing good hybrid animals.

6. More preference should be given to the less water consuming plants and tress having some economic value.

7. Underground water potential, should be fully utilized.

8. Research relating to climatic, edaphic and biotic aspects should be utilized to make management more cognitive and efficient.

9. Saline water treatment plants should be utilized more extensively

10. No foreigner should be allowed to do tourist business in Jaisalmer areas.

5. Nisar Ahmed Sheikh, &
Kanta Prasad Sharma,
Govt. College, Beawar.

The workshop in recent advances in monitoring the process of desertification, organized by deptt. of geography, University of Jodhpur has thrown sufficient light on the basic question of advancement of desert in eastern Rajasthan. A sizeable group of scholars admits that desert is not expanding, it shows that there is no expansion of desert in eastern Rajasthan. And assuming this view, we have to check only the process of desertification in western Rajasthan. And to check this following measures should be taken:

1. We should first be sure of our problem before planning a proper study of the areas.

2. Enhance agricultural development by (a) increasing agricultural facilities through canals, tube wells etc.,
   (b) adopting dry farming methods, and
   (c) using the seeds having quick germination and short growing season.

3. Change in live-stock pattern. Maximum use of camels in every field of life should be made. Because this is the only animal of desert, who plays the least part in the process of

desertification. It chews only the upper leaves of the trees and the cushiness form of its feet disturb the sand least. The study of this kind has been conducted in African desert, and the results are positive one.

4. Stabilize sand dunes by proper management and plantation of drought resistant grasses and shrubs.

5. A shelter belt of trees can be planted in the marginal areas along the 25 cm isohyet and afforestation on large scale should be done in western Rajasthan.

6. Alternative sources of energy should be provided to city dwellers, so the commercial cutting of the trees can be checked.

6. O.P. Sharma,
Head, Deptt. of Geog.,
D.A.V. Degree College,
Lucknow University

The national workshop on "Recent advances in monitoring the process of desertification" sponsored by U.G.C. and held under the direction of Prof. A.K. Tewari, Head, Geography Deptt., Jodhpur University is a very successful and inspiring step to get the participants coming from various areas of the country, acquainted with the deteriorating desert conditions in the region. I am really benefitted by the lectures delivered by several resource personnels of repute. The workshop has provided me with the comprehensive techno-scientific knowledge of the process of desertification, its various causes of origin like the environmental degradation and imbalances in the eco-system of this hot arid and semi-arid area of the country.

The knowledge of the recent technique and tools like remote sensing explained in the workshop will certainly help in providing sufficient data and its interpretation with regard to the mineral, soil, water and biotic resources of the region.

To ameliorate the environmental conditions of the land and its people together there is a prime need for desert development planning. Some measures like afforestation, pasture development, development of horticulture, animal husbandry, increase in the suitable cropping pattern, increase in the irrigation facilities may convert this region as a self-sufficient and economically viable unit. During the field exercises and visit to surrounding environment I have also observed that there is also a prime need to educate the people to avoid harming the eco-systems of the region. Field study tours and visit to Central Arid Zone Research Institute and Photo-interpretation Laboratoty, Kailana water-shed. Rangeland Study, Mandore Garden and beautiful picturesque surrounding of Jodhpur has provided with the physico-cultural information of the areas. Similarly the cultural programmes arranged by the students of Geography Deptt. has embodied the true cultural picture of Rajasthan's dress, folk song, dance and drama.

7. Prof. P.N. Pandey,
Manipur University, Imphal.

The lectures delivered by the experts on various topics has been very much beneficial specially to me who is in very remote and isolated part of the country in Manipur. The visit to the CAZRI has given an impression of measures taken by the Institute to check and to make the Biblical quotation—'The desert will bloom', a true and correct picture.

The visit to other areas has been equally important and beneficial by providing best picture of the desert region.

The cultural programme presented by the students of the Deptt. of Geography has given a true picture of the cultural heritage of Rajasthan. It entertained all the participants very well. The students co-operated in the workshop, in the mess arrangements and as guide during visit of different educational excursions.

The site of the workshop is very good and I feel this should be preserved for such academic pursuit in the future too.

In the last I congratulate Prof. A.K. Tewari, Director of the Workshop that he planned the workshop very well. His selection of team shows his super ability of administration besides his educational persuit.

The workshop has been very successful as far as my observations are concerned. All the aspects and factors have been taken into consideration to make the workshop a successful and it has been truly successful.

8. Dr. P. Viswanadham,
Deptt. of Geography,
Andhra University,
WALTAIR 530003.

1. From the deliberations of the scientists from CAZRI, it is clear that the area is endowed with hugee potentialities of some climatic resources like solar energy and wind force. These resources being renewable in character, will stand for any level of exploitation. The development programme must be oriented towards making maximum and best utilization of these resources. Use of solar energy and wind power, as a substitute to fuel and electric power, not only meets the domestic and industrial demands for energy but also minimizes to a great extinct the non-judicious exploitation of non-renewable resources like biotic and mineral fuels.

2. Aridity, which has resulted from acute water deficiency, can be reduced by choosing appropriate crop and by growing it in the appropriate season which matches will with the period of moisture supply. Matching of crop seasons with the climatic seasons, may yield better results.

3. Some parts of Rajasthan do receive surplus water during the rainy season. In rational water use planning, the water surpluses have to be carefully conserved for proper utilization during lean seasons of water deficiency. This kind of planning may be made both for receiving drinking water as well as for irrigation.

4. Since the state experiences significant abnormalities of thermal efficiency throughout the year, if hygric conditions are also made favourable. the areas will support the growth and development of natural as well as introduced vegetation. This condition can also be monitored by practising cultivation of such crops whose temperature and sunshine demands are high and moisture needs are lower.

5. It is observed that some of the techniques developed by CAZRI are not adopted by the people. In order to get over this problem, it is recommended that a separate mechanism may be developed so that these techniques and devices are easily adapted by the users.

9. M. Istiaq, Jamia Millia Islamia,
New Delhi.

The Western part of India, especially West of Aravalli is suffering from desertification. Both biotic and abiotic factors are found responsible in the process of desertification.

In the present workshop, this problem has been studied systematically with the aids of remote sensing techniques and computers. The workshop could receive many positive ways for checking the process of desertification such as afforestation, reducing the population pressure on the marginal lands, checking of over grazing and deforestations etc.

Besides these, following points should also be given proper attention:

1. emphasis is to be given how best human resources can be utilized without deteriorating the desert sands. Tourism is one of the field where a large section of population may be engaged.
2. grazing – one of the largest economic activities in the areas should be expanded and properly managed.
3. establishment of milk processing industries.
4. plantation of date palm should be encouraged which will yield economic returns.

10. R.P. Chaturvedi,
Head Deptt. of Geography,
Govt. College, Beawar.

The climate of the area

Heron in his Memoirs has mentioned that the areas has been humid in the past. He referred to epic age that Pandavas stayed in dense forests of Saraswati & Ghaggar valleys. Furthermore, it is evident from the Palana lignite mines that the area had been forested in the past geological ages.

What factors were responsible for this change in the climate from humid to arid.

Over grazing

If the areas is to be protected from over grazing which lead to desertification, the ecology of live-stock is to be changed. Cattle should be preferred in canal areas and sheep and goat in other areas. But the density of animals must be low everywhere.

Finally, some sort of changes may be brought in the habits of the people of this area, like food habits, occupation etc. Nomadism should be checked. They should be made sedentary by providing more canals in the region. Cutting of trees should be checked, alternative fuel should be provided by Govt. and other social institutions so that they may shift over to LPG gas, Gobar gas etc. in place of their dependence on firewood. This cultural change in the society may bring some involvement of the people of the area in restricting the desert area. In my opinion it is the people of the area to be made more cautions regarding the desertification, rather than the Govt. and other social institutions.

11. Dr. R.D. Gurjar I
Assistant Professor,
University of Rajasthan,
Jaipur.

The problem of the desertification is of course, a very concern of the home and therefore this workshop was indeed needed at the crucial juncture. No workshop can render magical results over night but this workshop has been very much successful in exposing the various dimensions of the serious menace of desertification, leading to the disasters to the already cripped economy of Rajasthan.

1. The term desertification generally misunderstood with the process of sand dune shiftings and high velocity winds has been variably explained in its true sense.

2. A wide range of lecturers of physical, biotic and social aspects of this problem has very brilliantly been dealt with and the various scientists from CAZRI and Deptt. of Botany, University of Jodhpur have exposed the concerned aspect of their disciplines and now look into the geographer who fuses the result if not the methods of a host of other sciences. Now the ball is in the court of a geographer who should develop a balanced concept of desertification and come forward with a practical and rational line of action to combat this emerging crisis.

3a. Various scientists have assessed the problem very carefully but from the deliberations of CAZRI scientists it appears that they have proceded with a prior hypothesis of desertification, hence the possible imbalances are necessarily to be removed.

3b. The measures suggested by the scientists are plagued with the negative aspect of remady. They have suggested to check the overgrazing by reducing the population of animal husbandry, to ban the felling of trees for fire wood, but without any alternatives to the consumer. In fact, such measures are not rational and in harmony with the concept of development. Such nagative doctrines may aggravate the social desertification and is bound to decrystalise the social fabric.

Hence here is the question of accommodating the interest of class people suggesting some practical measures imbibed with positive concept of growth.

4. This is the crucial hour in which role of geographer has been challanged and geographers (all participants) should take a firm pledge to leave no stone unturned in performing this pious duty of harmonising the interest of all with positive framework the very existence is in peril.

Lastly, the very success of this workshop is in giving a timely alarm to all the champions of human beings and this very arm now awaits the sincere efforts of participants.

S. C. E. R. T. [illegible]
Library

Dr. Anil K. Tewari is Professor and Hea of the Geography department, University o Jodhpur (India). He has been working in th area of desert development for the last thre decades. His contributions include researc papers, text books, monographs and articles on regional development, landuse, tribal food systems, water conservation, remote sensing and perception of desert environment published in India and abroad. He has widely travelled and lectured in the Universities and research institutions of France, U.S.A., U.S.S.R. and Mexico. He is also member of several national and international bodies of advanced research in desert environment.

COMBATING DESERTIFICATION IN DEVELOPING COUNTRIES

Edited by **Dr. J. K. Jain**
University of Jodhpur, Jodhpur/India

The issue of desertification is globally important and subject to lively research. Desertification is occurring everywhere in the world, but it is accelerating most rapidly in the developing world. Currently, about 35 per cent of the world's land surface is at risk, and the livelihoods of 850 million people who live there are directly threatened. Human overexploitation of lands through overcultivation, overgrazing, deforestation, poor irrigation practices, bad management and the rural neglect are some of the underlying causes of desertification menace. Despite considerable contributions and prodigious efforts of the world's nations to halt the process of desertification, the problem has rather increased in severity over the last decade due to the absence of coherent planning.

The Sahelian drought of 1968-73 focused governmental and public attention on the problem of desertification as a whole. In response, the United Nations Conference on Desertification (UNCOD) was convened in Nairobi, Kenya, from August 29 to September 9, 1977. The present book is based on twenty country reports prepared for and presented to this Conference. The countries, scattered over the four continents of the world, include Australia, Afghanistan, Bangladesh, Cyprus, India, Jordan, Kuwait, Nepal, Pakistan, PDR of Yeman, Botswana, Ethiopia, Ghana, Libya, Nigeria, Somalia, Tanzania, Greece, Portugal and Yugoslavia. The desertification problems and their solutions have been discussed with frequent references to the related country. An effort has been made to modify the reports to include the information of the last decade. The book will be found useful by decisionmakers, planners, administrators, specialists and technicians of developing countries facing desertification problems.

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